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ORIGINAL ARTICLES

STUDIES IN GANGETIC ALLUVIUM OF UNITED PROVINCES

II. SOILS OF SANDILA *TAHSIL* IN HORDOI DISTRICT

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(Received for publication on 19 December 1945)

(With one text-figure)

Sandila *tahsil* forms the south-eastern part of the district of Hardoi in the central United Provinces and lies in latitude 27°4′ north and longitude 80°30′ east, being nearly mid-way between Lucknow and Hardoi. It has a total expanse of about 558 square miles and the entire area has been sub-divided administratively into four *parganas* (small sub-divisions), *viz.* Sandila, Gondwa, Kalyanmal and Balamau.

(a) Topography and soils

In the north and north-east the *tahsil* is bounded by the river Gomti, which flows in tortuous curves and in the west is the river Sai. Between these two rivers there is an expanse of apparently level country which can be sub-divided broadly into three parts depending upon the topographical conditions.

These are: (1) the tract of uplands between the watershed of the Gomti and that of the Behta, a small rivulet which originates in the north-west of *pargana* Sandila, nearly eight miles from the Gomti and flows in the centre of the *tahsil*. The soil of this area is reputed to be sandy-loam in the north but improves slightly in texture as it approaches the Behta. There are several *jhils* (low-lying pockets) in this area which are liable to inundation during the rains.

(2) The land lying between the Behta and the Lucknow Branch of the Sarda Canal is occupied by a low-lying imperfectly drained tract having large stretches of *usar* (alkaline) lands. This is approximately six miles in breadth in the south-east but broadens to nearly eight miles in the north-west. The total length is about 16 miles.

(3) A strip of land, nearly eight miles broad and slightly narrowing down as it goes north, between the Lucknow Branch of the Sarda Canal and the river Sai is occupied again by a slightly high-lying area in which the soil is medium loam in texture [Zaidi, 1931].

(b) Agriculture

The total cultivated area of the *tahsil* is assessed at approximately 210,000 acres, out of which nearly 60 per cent is cultivated during the *rabi* and 53 per cent during the *kharif*—13 per cent being the area which is double-cropped. Irrigation is not very deficient, the percentage of wet to total cultivated area in 1931 was only 32, but this has now increased to 56 as a result of the introduction of the Sarda Canal. About 24·0 per cent of the cultivated area is reported to grow wheat alone or mixed and 21 per cent barley in the *rabi*. The chief crops of the *kharif* are the millets (*jowar* and *bajra*); the acreage under these is assessed at about 23 per cent of the total cultivated area. Paddy occupies only about 8 per cent and pulses, chiefly *arhar*, 7 per cent. The area under non-food crops, mainly sugarcane, is reported to be 18 per cent.

The distribution of the crops on the main soil types described in the present paper is as follows:

Type 1 soils usually grow sugarcane, wheat and barley with *jowar* as the main *kharif* crop. The better classes of land in soil type 2 grow wheat and barley in the *rabi* and *arhar* and *jowar* in the *kharif*; but on lighter types only a mixed crop of *arhar* and *jowar* or *bajra* is possible. Type 3 soils usually grow paddy in the *kharif* and barley or gram in the *rabi*. Wheat is also cultivated on good quality loams with better drainage conditions.

(c) Climate

Unfortunately the complete meteorological data for Sandila proper are not available. In Table 1 the average rainfall data for Sandila are presented along with other data for Lucknow. Lucknow is only about 30 miles east of Sandila and the climate of the two places from the soil point of view is not expected to vary much. From Table I it can be seen that the average total rainfall for the year is only 34·79 inches and that the maximum precipitation takes place during the months of June, July, August and September when approximately 31 inches of rain are usually received. The other four inches are received during the remaining part of the year. Winter rains are scanty. The highest temperatures are attained during the months of April, May and June when the relative humidity is also low. During the hottest part of the year the absolute maximum temperature is recorded to be as high as 115°F. During these months, therefore, considerable desiccation of the soil takes place. Winters are never very severe and are usually frost free. The coldest months are those of December and January and the absolute minimum has been recorded as low as 34°F. However, during these months the relative humidity is fairly high. The climate in general can be characterized as semi-arid (Table I).

TABLE I

Rainfall data for Sandila (average of 42 years) and other meteorological data for Lucknow (average of 22 years)

Months	Rainfall (inches)	Temperature			Relative humidity (per cent)
		Maximum °F.	Minimum °F.	Mean °F.	
January	0·73	74·0	46·7	60·4	81·9
February	0·38	78·8	50·9	63·9	71·9
March	0·32	91·5	60·3	75·9	52·7
April	0·11	102·4	70·9	86·7	40·1
May	0·53	105·0	77·8	91·4	46·1
June	4·60	100·5	81·3	90·9	69·3
July	10·65	92·2	79·3	85·8	83·7
August	10·00	90·3	78·6	84·4	87·5
September	5·68	92·1	76·5	84·3	81·3
October	1·38	91·2	65·5	78·4	72·2
November	0·11	83·3	52·8	68·0	75·5
December	0·30	75·7	46·2	61·0	81·9
Average	34·79	89·8	66·2	78·0	70·3

Lang's factor for the locality is 35 mm. per degree centigrade and Meyer's N.S. quotient 124·7. These figures clearly show that the climate of the locality would favour semi-arid type of soil formation. According to Jenny [1929], the N.S. quotient for the chestnut-brown steppe soils of the United States of America is 100-180; and it would appear that the climatic soil zone for the locality under survey may on these considerations be a type of chestnut-brown soil. However, it may be noted that the limit of annual temperatures in the United States of America for the chestnut-brown zone is between 8°-12°C., but the mean annual temperature of the Sandila *tahsil* would be approximately 25°C.

(d) Methods

The details of technique adopted for the survey of soils were the same as those reported in Part I of this series [Mukerji, Agarwal and Mukerji 1944]. A number of pits were dug at sites selected

at random; and the morphological characters as well as field reactions were recorded on the soil profiles *in situ*. Soil samples were brought to Cawnpore where detailed chemical, mechanical and physico-chemical analyses were made.

Samples of the size of 2 mm. were used for all analysis. Mechanical analysis was carried out by the international pipette method using ammonia as the dispersion agent. Hydrochloric acid extract was made according to the method prescribed by the A.E.A. [Wright 1938]. pH values were determined in N-KCl using hydrogen electrode. Water extract was prepared from a 1 : 5 soil-water mixture and filtered with the help of a Chamberlain filter candle. The individual exchangeable bases were determined in the leachate prepared through the use of neutral ammonium acetate, the total of which was reckoned as the total exchangeable bases.

Experimental

On the basis of a large volume of data collected in the course of the survey, the soils of the Sandila *tahsil* have been classified into three distinct soil types, the distribution of which is shown on the map (fig. 1). The profile descriptions along with the analytical data for a representative soil profile under each type are given below and the results are discussed specially in reference to their pedological aspects.

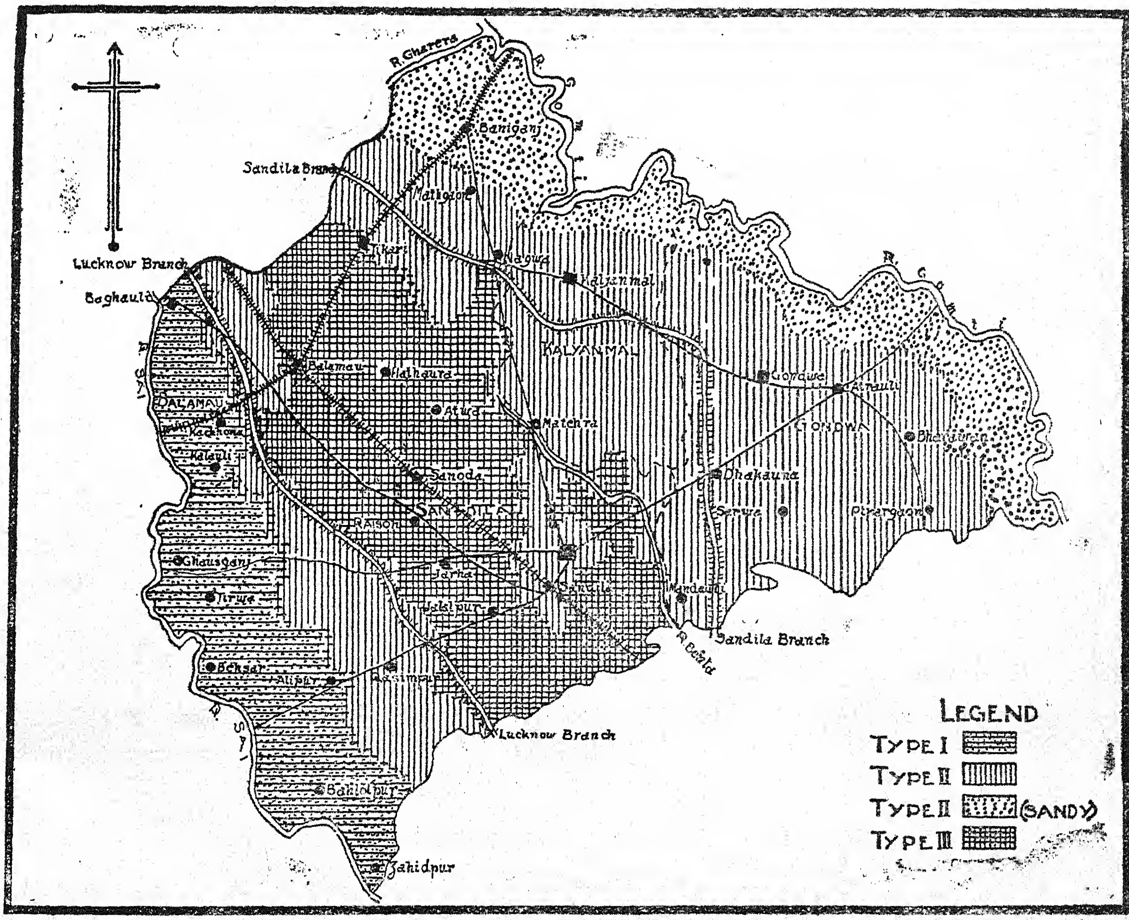

Fig. 1. Tahsil Sandila—Soil Types

(Scale 1 i --4 miles)

(i) *Type I*

The soils belonging to this type occur towards the west of the *tahsil* bordering the Sai river. This belt of land has an average breadth of about four miles and is slightly high-lying. The high bank of Sai is well marked but is sandy and liable to inundation during high floods. The soils of the other part of the zone are good sandy loams. The profile description is given below :

Morphology

I. 0—1 ft. 2 in. Whitish grey loamy soil without any structure ; loosely packed ; non-calcareous, gritty and slightly alkaline.

II. 1 ft. 2 in.—1 ft. 10 in, 1 ft. 10 in.—3 ft., 3 ft.—4 ft. Slightly greyish yellow loamy soil with more of clay ; granular in structure ; more compact than the top layer ; calcareous and alkaline ; embedded with small fragments of *kankar* towards the bottom ; roots visible up to 3 ft.

III. 4 ft.—5 ft., 5 ft.—6 ft. Light yellowish grey tending to be ashy-grey at the bottom ; sandy in texture ; highly calcareous material rather loosely held ; embedded with big sized *kankars* about 1 in.—1½ in. in diameters ; markedly alkaline.

The profile was sampled in the village Kachhauna from a cultivated field which is being irrigated by wells. The soil is reported to be highly fertile and usually bears a good wheat crop. The topography is flat and the water table is 15 ft. during the summer and 10 ft. during monsoons. From the morphological description it is clear that the soil has developed over a calcareous parent material and that there are slight signs of eluviation of clay in the lower layers.

The data for the mechanical and other analyses are given in Table II.

TABLE II

Mechanical and other analyses of Sandila soils (Type I)

Particulars	0-1 ft. 2 in.	1 ft. 2 in.—1 ft. 10 in.	1 ft. 10 in.—3 ft.	3 ft.—4 ft.	4 ft.—5 ft.	5 ft.—6 ft.
	A		B		C	
Coarse sand percentage	0·48	0·26	0·20	1·06	0·97	3·20
Fine sand percentage	55·25	36·03	31·45	36·67	41·25	53·23
Silt percentage	26·10	31·45	30·20	29·80	28·10	21·25
Clay percentage	17·50	30·10	31·90	27·75	23·50	15·50
Organic carbon percentage	0·312	0·172	0·140	0·125	0·125	0·109
Total nitrogen percentage	0·0504	0·0490	0·0392	0·0462	0·0364	0·0210
*p*H	7·3	7·6	7·8	7·9	7·9	7·8
Moisture equivalent percentage	27·1	28·7	31·0	29·2	2·71	29·0
Water holding capacity percentage	44·7	53·3	51·1	54·6	53·2	52·4

The data for the mechanical analysis show that the top layer contains little clay, but that clay has been eluviated into the lower horizon and is distributed more or less uniformly up to a depth of 4 ft. The bottom two layers are again poor in clay. Fine sand content is high at the top which confers on this layer a typical open texture but decreases again in the B-horizon only to increase in the last layer. The greater colloidal matter content of the clay B-horizon makes it compact and moderately impervious to water. Nitrogen and organic matter are high at the top but decreate to a very low figures as we go down in the profile.

The chemical composition of the soils belonging to this type is shown in Table III.

TABLE III

Analysis of the hydrochloric acid extract of Sandila soils (Type I)

Percent ais dry basis

Particulars	0—1 ft. 2 in.	1 ft. 2 in.—1 ft. 10 in.	1 ft. 10 in.—3 ft.	3 ft.—4 ft.	4 ft.—5 ft.	5 ft.—6 ft.
	A		B		C	
Moisture	0·17	0·27	0·31	0·24	0·21	0·15
Loss on ignition	1·61	1·93	2·11	2·61	1·94	2·78
Total insolubles	86·15	80·41	73·89	72·53	74·20	70·86
Fe_2O_3	2·48	2·00	3·44	2·96	2·80	1·96
Al_2O_3	5·54	9·53	11·24	12·12	8·28	8·84
CaO	0·43	0·62	2·04	2·88	3·00	5·81
MgO	1·04	1·11	1·40	0·72	1·91	1·92
K_2O	1·22	1·21	1·46	1·56	1·16	0·88
P_2O_5	0·111	0·119	0·080	0·098	0·126	0·143
CO_2	0·00	0·23	1·05	2·67	3·48	5·44

Moisture figures show the same trend as clay but the loss on ignition figure is higher for the bottom most layer. This high ignition loss is not accounted for by the clay content. The top layer in every case was found to be more siliceous than the B-horizon. It seems that silica, being more resistant to weathering than the other components, is left behind while the other materials are leached out of the upper horizons. This fact is further corrobotated by the hydrochloric acid insolubles figures for B-horizon being in general slightly more than those for the C-horizon. Sesquioxides show accumulation in the B-horizon. The distribution of these constituents is evidently been influenced by the distribution of clay in the soil profile. Lime and magnesia increase gradually with depth. The magnesia content seems to be fairly high showing the richness of the parent material in this ingredient. The soil seems to be rich in potash too, the vertical distribution of which in A and B-horizons seems striking. The accumulation of silica in the top layers and eluviation of sesquioxides, specially alumina, in the bottom layers are signs of weak podsolization.

The results of the analysis for the water extract of the soil profile are presented in Table IV and those for the exchangeable bases in Table V.

TABLE IV

Analysis of water extract of Sandila soils (Type I)

Depth	Total solids (per cent)	Percentage of total cations			M. e. per cent.			
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4
0—1 ft. 2 in.	0·0452	30·0	60·0	10·0	*nil*	0·50	0·06	Traces
1 ft. 2 in.—1 ft. 10 in.	0·0552	32·5	46·0	21·5	*nil*	0·67	0·08	Traces
1 ft. 10 in.—3 ft.	0·0488	39·9	37·5	23·6	*nil*	0·79	0·06	Traces
3 ft.—4 ft.	0·0900	33·3	42·8	23·9	*nil*	1·15	0·08	Traces
4 ft.—5 ft.	0·1104	31·8	53·2	15·0	*nil*	1·00	0·72	Traces
5 ft.—6 ft.	0·0876	41·4	41·4	17·2	*nil*	1·04	0·16	Traces

The data for the analysis of the water soluble salts of the soil profile show certain very interesting characteristics. The total solids are not high but have a tendency of accumulation with depth probably as a result of the presence of the clayey B-horizon. Of the cations, calcium and magnesium form the majority and in the top layer the monovalent ions are present only to an extent of 10 per

cent ; but in the B-horizon they increase to about 24 per cent decreasing again to 15-17 per cent in the C-horizon. The accumulation of the monovalent ions in the B-horizon coupled with its clayey nature is responsible for its indurated character. The majority of the anions consists of bicarbonates. Carbonates are absent, sulphates are present in traces and chloride content is small. Bi-carbonates show a distinct trend of being washed down in the profile. The higher bi-carbonate content of the lower layers confers on them a markedly alkaline character. The striking feature is the richness of the extract in magnesium as compared to calcium, the water extract throughout being of a predominating magnesian character.

TABLE V

Analysis of the exchangeable bases of Sandila soils (Type I)

Depth	Total exchangeable bases m.e.	As percentage of total exchangeable bases			
		Ca	Mg	K	Na
0—1 ft. 2 in.	10·33	67·76	29·91	2·33	*nil*
1 ft. 2 in.—1 ft. 10 in.	16·63	69·75	28·44	1·81	*nil*
1 ft. 10 in.—3 ft.	15·07	57·73	37·42	2·78	2·07
3 ft.—4 ft.	11·84	38·85	52·53	3·53	5·07
4 ft.—5 ft.	11·52	38·19	50·52	1·56	9·73
5 ft.—6 ft.	7·57	25·09	65·39	9·51	*nil*

The total exchange capacity is not high. The bulk of the exchangeable bases consists of divalent cations. The monovalent bases are not more than 11 per cent, being higher in lower layers, of the divalent bases, calcium forms the majority in the first three layers but the position becomes reverse in the last three layers, where magnesium comes out as the predominating cation. Sodium saturation is nil in the first two layers and increases with depth reaching a maximum value of 9·73 in the fifth layer. The richness of the water extract in magnesium was evident from Table V. It appears that the exchange complex gets more saturated with magnesium in the bottom layers than in the top layers although the magnesium content of the exchange complex in the top layers is high enough. The B-horizon is, further, rich in sodium cation and this makes the clay of that horizon slightly sticky and deflocculated in water. The potash saturation is low throughout except in the last layer.

(*ii*) *Type 2*

This soil type occurs towards the eastern part of the *tahsil* in the area between the river Gomti and the rivulet Behta. The belt of the land is approximately 16 miles in breadth in the south but converges to about eight miles when it traverses north. There is another strip of land on the other side of the *tahsil* on which this soil type occurs bordering the area occupied by type 1 soils. These two belts of land presumably meet somewhere further north. Near the river Gomti there is a narrow low-lying stretch of land, the soils of which are similar genetically to those under this type but are highly sandy in character. The distribution of type 2 soils, along with its sandy sub-type, is shown on the map (fig. 1).

The soil profile is of the following type :

Morphology

I. 0-1 ft., 1 ft.—1 ft. 9 in. Light grey or browinsh grey gritty soil ; loamy in texture ; loosely packed ; non-calcareous and slightly alkaline to neutral in reaction ; roots visible.

II. 1 ft. 9 in. —3 ft., 3 ft.—4 ft. 4 in. Light grey with some shade of yellow or red ; slightly compact ; clayey loam in texture ; granular in structure ; brown rust mottlings together with dark brown concretions of the size of the pea visible ; non-calcareous and neutral to slightly acidic in reaction.

III. 4 ft. 4 in.—5 ft., 5 ft.—5 ft. 1 in. Light brown to yellowish brown sandy soil ; rather loosely held ; rust streaks visible ; non-calcareous and neutral in reaction.

A number of profiles belonging to this soil type were studied. Mechanical composition along with other data of a typical profile sampled from village Atrauli are given in Table VI.

TABLE VI

Mechanical and other analyses of Sandila soils (Type 2)

Particulars.	0-1 in.	1 ft.—1 ft. 9 in.	1 ft. 9 in.—3 ft.	3 ft.—4 ft. 4 in.	4 ft. 4 in.—5 ft.	5 ft.—5 ft. 11 in.
	A		B			C
Coarse sand percentage	0·85	1·02	1·48	2·10	0·15	0·16
Fine sand percentage	51·23	52·96	43·32	42·11	49·45	53·75
Silt percentage	24·40	24·85	23·55	21·08	21·35	20·25
Clay percentage	15·35	18·27	26·45	28·08	26·60	22·10
Organic carbon percentage	0·2166	0·1615	0·1330	0·1007	0·1045	0·0869
Total nitrogen percentage	0·0700	0·0672	0·0546	0·0546	0·0462	0·0533
*p*H in KCl	7·8	7·3	7·2	7·2	7·1	7·0
Moisture equivalent percentage	26·0	22·9	26·4	28·4	27·0	28·1
Water holding capacity percentage	44·6	45·7	46·1	48·6	51·3	51·0

The results of mechanical analysis show that there are feeble signs of eluviation of clay into the lower layers and that the fine sand content is high at the top, decreasing in the B-horizon and increases again in the bottom most layer. Coarse sand content is high in the top four layers as compared with the bottom two layers. Organic matter decreases regularly with depth and so does total nitrogen. *p*H is slightly alkaline at the top and decreases gradually till it becomes more or less neutral at the bottom. The profile does not contain any calcium carbonate. The characteristic difference between type 2 and type 1 profiles described previously is the non-calcareous nature of the former which confers on this type entirely different properties.

The composition of the hydrochloric acid extract of the soils belonging to type 2 is shown in Table VII.

TABLE VII

Analysis of the hydrochloric acid extract of Sandila soils (Type 2)
(Per cent air dry basis)

Particulars	0—1 ft.	1 ft.—1 ft. 9 in.	1 ft. 9 in.—3 ft.	3 ft.—4 ft. 4 in.	4 ft. 4 in—5 ft.	5 ft.—5 ft. 11 in.
	A		B		C	
Moisture	1·01	0·92	2·52	1·22	1·59	1·13
Loss on ignition	3·22	2·12	2·14	3·38	2·60	2·95
Total insolubles	86·05	86·05	82·37	78·67	79·18	80·00
Fe_2O_3	3·20	3·60	4·24	5·48	5·40	4·92
Al_2O_3	4·00	4·24	6·66	7·62	10·86	7·76
CaO	0·42	0·49	0·38	0·43	0·38	0·28
MgO	0·91	0·93	1·16	1·29	1·20	1·30
K_2O	0·20	0·94	0·92	1·14	1·01	1·14
P_2O_5	0·09	0·09	0·09	0·08	0·07	0·13
CO_2	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*

Moisture follows the same trend as the distribution of clay and so are in general the loss on ignition figures. Hydrochloric acid insolubles are high at the top two layers and decrease in the B-horizon increasing slightly again in the last layer. This behaviour is correlated with the fine sand content of the profile. Sesquioxides follow the distribution of clay being higher in the B-horizon. Lime seems to be completely leached out of the profile but magnesia and potash show signs of accumulation

with depth. It seems that magnesia leaching started after the entire amount of lime had been washed out of the profile. From the data for type 1 soils we had evidence of the richness of the parent material in magnesia, but it appears that in the above type, although calcium has been leached out more or less completely, magnesia leaching is still in progress. Table VIII contains the results of the analysis of the water extract and Table IX those of the exchangeable bases.

TABLE VIII

Results of the analysis of the water extract of Sandila soils (Type 2)

Depth	Total solids per cent	Percentage of the total cations			M. e. per cent			
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4
0 in.—1 ft.	0·080	13·6	53·2	33·2	*nil*	0·043	*nil*	Traces
1 ft.—1 ft. 9in.	0·080	7·9	63·3	28·8	*nil*	0.043	*nil*	Nil
1 ft.9 in.—3 ft.	0·072	5·1	59·8	35·1	*nil*	0·086	*nil*	Traces
3 ft.—4 ft. 4 in.	0·060	7·9	64·0	28·1	*nil*	0·033	*nil*	Nil
4 ft. 4 in.—5 ft.	0·074	2·9	73·5	22·6	*nil*	0·016	*nil*	Traces
5 ft.—5 ft. 11 in.	0·080	4·8	38·0	57·2	*nil*	0·040	*nil*	Traces

TABLE IX

Exchangeable bases in Sandila soils (Type 2)

Depth	Total exchange-able bases m.e. per cent	As per cent of total exchangeable bases			
		Ca	Mg	K	Na
0—1 ft.	8·80	76·2	11·4	4·1	8·4
1ft.—1 ft. 9 in.	9·76	73·0	19·3	3·7	4·3
1ft.-9 in.—3 ft.	11·12	72·0	25·2	1·1	1·8
3ft.—4 ft. 4 in.	11·84	62·6	23·7	2·3	11·8
4ft. 4 in.—5 ft.	9·60	68·8	20·5	0·6	9·8
5ft.—5 ft. 11 in.	9·28	64·5	30·0	0·6	4·5

The data on the analysis of the water extract show that the total water soluble solids are high at the surface. Magnesium has a tendency of accumulation with depth whereas calcium shows no such behaviour. This corroborates the finding that the profile exhibits magnesium leaching to a greater degree than calcium leaching. The last layer is unusually rich in monovalent cations. Of the anions, bi-carbonates form the majority and only traces of sulphates are present. The absence of chlorides is significant showing greater degree of leaching than what was found in type 1 profile.

From the data on exchangeable bases it is evident that the first two layers are slightly lower in total exchangeable bases but these increase in the next two layers and again fall in the last two layers. This behaviour seems to be correlated with the clay content of the soil. Exchangeable calcium is highest at the surface and shows a minimum value at the fourth layer. It increases slightly in the last two layers. Exchangeable magnesium is low in the A-horizon, becomes more in the B-horizon and is highest in the C-horizon. Divalent exchangeable bases follow in general the trend found in the water extract. The value for the exchangeable potash has been found to decrease

with depth and in the last two layers it is unusually low. The saturation with sodium falls from 8·4 per cent in the first layer to 1·8 per cent in the third layer but becomes 11·8 and 9·8 per cent in the fourth and the fifth layer, respectively. It again falls in the last layer.

(iii) Type 3

The soil type described under this head occurs as an island in the region occupied by soils of type 2 and lies on lightly lower topographical conditions. The landscape in the area occupied by soil type 3 has been disfigured at places by large stretches of *usar* (alkaline) lands. Pedologically this type is an intrazonal type being type 2 with more solentzic features. A typical description of the profile in which salinization process has not progressed to an extent to form solentzic soil is given below:

Morphology

I. 0-2 ft. Brownish grey soil with yellowish tinge; loamy in texture; gritty and without structure; no concretions; loosely packed; non-calcareous and neutral in reaction.

II. 2 ft.-3 ft., 3 ft.-4 ft. 6 in. Brownish grey soil; loamy in texture; without structure; black concretions being iron deposited round about quartz particles; slightly more compact; non-calcareous and neutral to alkaline in reaction.

III. 4 ft. 6 in.-5 ft. 3 in., 5 ft. 3 in.-6 ft. Lighter brown soil; sandy loam in texture; gritty and without structure; no concretions; loosely packed; non-calcareous; neutral to alkaline in reaction.

Although the second layer shows very slight signs of induration this does not appear to be due to clay. The clay content in this type of soil was found to be more or less constant in the first two or three layers and then had a tendency to decrease downwards. The texture of the top soil can be described to be definitely heavier than what is met with under the previous two types. The presence of iron concretions in the B-horizon signifies the nearness of the ground waters. The mechanical and other general analyses of a typical profile sampled from the village Mandai, near Sandila proper are shown in Table X.

TABLE X

Mechanical and other analyses of Sandila soils (Type 3)

Particulars	0 ft.—2 ft.	2 ft.—3 ft.	3 ft.—4 ft. 6 in.	4 ft. 6 in—5 ft. 3 in.	5 ft. 3 in—6 ft.
	A	B		C	
Coarse sand percentage	2·05	4·80	0·90	0·27	0·22
Fine sand percentage	45·50	39·83	53·48	68·61	79·35
Silt percentage	24·55	24·65	18·70	12·30	7·40
Clay percentage	26·15	27·80	24·10	16·85	9·73
Organic carbon percentage	0·253	0·184	0·164	0·101	0·085
Total nitrogen percentage	0·0798	0·0322	0·0504	0·0518	0·0630
*p*H in N-KCl	7·0	6·9	6·9	7·1	7·0
Moisture equivalent percentage	25·4	27·2	27·0	21·5	17·1
Water holding capacity percentage	45·9	43·0	48·0	46·8	44·4

An examination of the data presented above clearly shows that the coarse sand fraction is comparatively high at the top layers which suggests that the soil has been subjected to slight erosion. The fine sand content increases with depth; whereas silt and clay fractions decrease downwards. These figures show that although the top soil is a moderately heavy textured soil, the bottom layer is still sandy. Organic carbon and total nitrogen also decrease with the depth of the profile. The *p*H in the present case is more or less constant, but in other profiles of this type, which were studied,

the pH is found to increase with depth. Moisture equivalent and to some extent the water-holding capacity follow the same trend as the distribution of clay.

The chemical composition of the soils of type 3 is shown in Table XI.

TABLE XI

Analysis of the hydrochloric acid extract of Sandila soils (Type 3)

(Per cent air dry basis)

Particulars	0 ft.—2 ft.	2 ft.—3 ft.	3 ft.—4 ft. 6 in.	4 ft. 6 in.—5 ft. 3 in.	5 ft. 3 in.—6 ft.
	A	B		C	
Moisture	1·54	1·75	1·54	1·07	0·54
Loss on ignition	2·54	2·89	2·30	2·13	2·80
Total insolubles	80·32	76·39	79·10	82·39	86·62
Fe_2O_3	4·64	4·84	5·16	4·04	3·60
Al_2O_3	8·05	11·63	7·57	7·26	6·00
CaO	0·50	0·49	0·31	0·35	0·43
MgO	1·15	1·43	0·50	0·56	0·90
K_2O	1·13	0·98	1·10	0·68	0·08
P_2O_5	0·10	0·08	0·08	0·07	0·09
CO_2	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*

Moisture figures indicate the same tendency as the distribution of colloidal matter. Insoluble matter in hydrochloric acid is higher in the bottom two layers which were also found to be lowest in clay and highest in fine sand content. Sesquioxides are lowest in the bottom two layers evidently due to the lower clay content. Lime seems to be completely leached out and the leaching of magnesia is not at all prominent as in the other two types. Potash also follows the same trend as the alkaline-earth bases. In short, it seems from a study of the distribution of clay and the bases, that vertical leaching in the soil profile has been more or less completely absent. For, with a sandy layer in the bottom, we should have expected a vertical distribution of all these constituents. This is due to the fact that the soil type described above is subject to very poor drainage during the rainy season and the water table is also comparatively higher being about 15-16 ft. on the average which comes very much nearer during the rains. The bad drainage condition is further responsible for the solentzic characters of the soil type in question.

The results of analysis of the water extract of the soils from the profile described are given in Table XII.

TABLE XII

Analysis of water extract of Sandila soils (Type 3)

Depth	Total soluble solids	Water percentage of the total cations			M.e. of anions			
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4
0 in.—2 ft.	0·0876	76·0	16·0	7·6	*nil*	0·48	0·35	0·034
2 ft.—3 ft.	0·0544	75·5	17·0	7·5	*nil*	0·30	0·17	0·052
3 ft.—4 ft. 6 in.	0·0688	76·5	16·6	6·9	*nil*	0·40	0·20	0·146
4 ft. 6 in.—5 ft. 3 in.	0·0688	83·2	11·2	5·7	*nil*	0·30	0·26	0·172
5 ft. 3 in.—6 ft.	0·1092	84·7	6·3	9·0	*nil*	0·14	0·25	0·294

The percentage of monovalent cations in the water extract is small and divalent cations throughout constitute more than 90 per cent of the total cations. The percentage of magnesium is also lower and calcium forms the majority of the cations in the water extract. The bulk of the anions consists of chlorides and bicarbonates. Bicarbonates accumulate at the top and carbonates are absent. The presence of sulphates and their leaching to lower levels is quite significant which is due to poor drainage in the profile.

The above profile, although shows evidence of bad drainage, is yet not in a state of advanced salinization and the soil condition is consequently not considered to be bad enough. The region, as has already been described, however, lies on an intrazonal soil type and a large percentage of the land is gradually turning into *usar*. The results of analysis of the water extract of a typical alkaline land found in the area are given in Table XIII.

TABLE XIII

Result of water analysis of a typical usar *profile in type 3 area*

Depths	Total water soluble solids	Percentage of total cations			M.c. of anions				pH
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4	
0 in.—1 ft.	0·398	8·2	7·1	84·7	0·64	2·45	0·17	0·25	8·6
1 in.—2 ft.	0·252	25·2	17·5	57·5	0·42	1·77	0·07	0·04	8·3
2 ft.—3 ft. 9 in.	0·156	34·3	25·0	40·7	0·20	1·76	0·06	0·03	8·2
3 ft. 9 in.—5 ft. 4 in.	0·149	35·0	15·0	50·0	0·32	1·61	0·08	0·02	8·2
5 ft. 4 in.—5 ft. 10 in.	0·096	34·7	21·0	44·0	0·02	1·00	0·11	*nil*	8·2

A consideration of the above data clearly shows the high alkaline character of the soil. The total water solubles are very high and so is the *p*H of the soil solution specially at the surface. Monovalent cations in the water extract are on the average much above 50 per cent of the total water-soluble cations. Although bicarbonates form the majority of the anions, the presence of carbonates in sufficient quantities in the extract is significant. One of the most characteristic feature is the accumulation of total water soluble solids, sodium and potassium, carbonates, bicarbonates and sulphates in the surface layers, whereas the greatest amounts of alkaline earth bases are found in the bottom layers of the profile.

Table XIV contains the results of the analysis of the exchangeable bases in the type 3 profile.

TABLE XIV

Analysis of exchangeable bases of Sandila soils (Type 3)

Depths	Total exchangeable bases m.e. per cent	As percentage of total exchangeable bases			
		Ca	Mg	K	Na
0 in.—2 ft.	12·64	65·27	25·16	4·75	4·82
2 ft.—3 ft.	14·50	67·24	30·14	2·63	*nil*
3 ft.—4 ft. 6 in.	13·41	62·59	34·62	1·12	1·67
4 ft. 6 in.—5 ft. 3 in.	10·31	64·66	33·33	2·01	*nil*
5 ft. 3 in.—6 ft.	8·73	53·38	38·03	6·87	1·72

Total exchangeable bases in the first and second horizon have more or less the same value but the third horizon is slightly poorer in bases. The distribution of bases follows the distribution of clay in the profile. Of the bases, calcium forms the majority and this cation together with magnesium amounts to more than 90 per cent of the total exchangeable bases. The relative proportion of magnesium to calcium in the exchange complex is also low and nowhere in the profile the percentage of saturation with magnesium becomes more than that with calcium. The magnesium content, however, increases with depth and, unlike the results obtained for the water extract in Table XIII, the content of calcium decreases. Sodium saturation is maximum at the surface layer and becomes almost negligible in the other succeeding layers. The behaviour of the exchange complex in respect of sodium is significant in view of the fact that this type of soil is reputed to possess poor drainage conditions. It appears that the surface two feet of the profile is being subjected to a slow but perceptible process of sodiumization as a result of sodium rich drainage waters which remain standing on it for a considerable period during the monsoons.

Discussion

The meteorological data of the locality, the soils of which were surveyed in the present investigation, point clearly to the conclusion that the climate would favour desert and semi-desert type of soil-formation. Rainfall deficiency and high summer temperatures are two of the most characteristic features of the locality. But the four months of the rainy season are particularly wet and this wet period follows an intense desiccation during the summer. These processes lead to a typical soil formation which differes fundamentally in many respects from the well known zonal types of the desert, semi-desert and arid parts of other countries.

As in other alluvial soils of the province, the first thing to be noticed about these soils is a very scanty horizon differentiation, but a textural profile can invariably be met with. A zone of lime accumulation is also found in one of the types described. Unlike other soils of the arid regions, the mechanical composition of the profile is not the same throughout. The top layer in most cases is sandy and this is followed by a slightly heavier horizon of accumulation. Clay has been found to have eluviated to lower layers resulting in slight induration and cementation of the horizon of illuviation. The bottommost layers again come out to be sandy. These facts show that the rainfall of the locality although scanty can nevertheless permit slight eluviation of colloidal matter into the lower layers leaving on the surface a highly silicious skeleton. Similar observations were made for the morphology of Unao soils described in Part I of this series [1946]. Nikiforoff [1937], in the course of the study of the morphology of soils in the Mojave desert in the United States as well noted one of the principal zonal characteristics of southern desert soils to be the presence of a reddish-brown clay layer in the lower part of the solum, but suggested, in view of the scanty rainfall, that this clay layer might be formed *in situ* by hydrolytic decomposition and not through a process of eluviation. In the central United Provinces, however, the amount of rainfall received is much more than what is recorded for Mojave desert and it seems doubtful if the above suggestion of Nikiforoff would hold good for this region.

A closer examination of the chemical composition of the soils reveals that chemical weathering of the soil complex is not well pronounced, since the distribution of silica and sesquioxides follow in most cases the distribution of clay in the soil profile. The topmost layer is more silicious in character and the content of this ingredient falls again in the B-horizon. Of the sesquioxides, iron seems to be more mobile than alumina and this fact suggests that the clay is more allitic, iron being present mostly in an uncombined form in the silicate complex. However, a detailed analysis of the separated clay portion which is proposed to be taken up in these laboratories at a later date, would throw more light on these factors. Lime has been washed down in all the three cases, but in the case of type 1 there has been an accumulation of lime in lower layers in the form of big calcium carbonate nodules. The behaviour of magnesia is interesting, since in all the three cases studied, its leaching has been found to be highly pronounced. The quantities of acid-soluble lime in all layers of the three types, except the last three layers of type 1 soil, have been found to be small in comparison with acid-soluble magnesia. Sigmond [1938] pointed out that in calcareous soils lime is leached

out on a larger scale than magnesia and that magnesia accumulates at the cost of lime. Joffe [1936] further states that in the case of brown soils solodization process favours the release of magnesium. It seems that in the soils described in the present paper, there has been a greater leaching of calcium as compared with magnesium due to the calcareous nature of the parent material and that with the start of the process of solodization magnesium leaching has further become prominent. The data on analysis of the water extract of the three soil types lend further support to these conclusions.

The results of analysis of the water extract clearly show that the soil solution is richer in magnesium than in calcium. This suggests, as has already been pointed out, that calcium leaching had been in progress in the past and now the process of the release of magnesium is much in evidence. According to Joffe [1936], this is an indication of the start of the process of solodization in the case of soils of the semi-arid regions. The total content of the monovalent bases in the water extract is fairly high and on this account one would expect high sodium saturation in the exchange complex as well. However, the sodium saturation in the exchange complex has not been found to be high, being on the average below 12 per cent of the total exchangeable bases. It is in this important respect that these soils differ materially from the soils of the adjoining district of Unao [1946]. Moreover, the exchange complex shows unusual richness in magnesium cation and the degree of saturation with this base increases with the depth of the profile. The degree of saturation with sodium cation also, in general, increases with the depth of the profile except in the case of soils belonging to type 3. It can be construed from these data that the process of solodization goes hand in hand with the process of the increase in the magnesium content of the exchange complex. It may be significant to note that these two bases, viz. magnesium and sodium, are not considered to be very desirable for the fertility of the land. In this connection it may be mentioned that Hissink [1938] noted magnesian character of the exchange complex of Dutch saline soils. He further showed that as the weathering in those soils increased exchangeable calcium was gradually replaced by exchangeable magnesium.

Summary

Soil survey of *tahsil* Sandila in the Hardoi district of the central United Provinces was conducted on modern pedological principles.

Three soils types (called type 1, type 2 and type 3) have been recognized and their morphological, chemical and other data have been presented and discussed. A regional map showing the distribution of these soil types has been prepared.

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THE EFFECT OF MANURING AND CROPPING ON THE VERTICAL DISTRIBUTION OF CARBONATES IN PUSA CALCAREOUS SOILS

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(With three text-figures)

The soil in the Indo-Gangetic alluvium around Pusa is highly calcareous containing 40 to 50 per cent of chalk and is a rare type occurring in India. Because of its rare occurrence both here as well as in other countries, little work seems to have been done with regard to the distribution of carbonates in different layers of such a soil. The only work of importance is that of McMiller [1926], who reports the concentration of carbonates in two Minnesota soil types. At depths varying from 12 to 27 in. below the surface, he found zones of pronounced carbonate accumulation, in which lime concretions were thickly distributed and the carbonate content ranged from 25·3 to 45·5 per cent. In the unaltered material below it varied from 7·7 to 22·7 per cent. The role of chalk in the Indo-Gangetic calcareous soil at Pusa was studied by the author [Das, 1931], but no data are available with regard to its distribution in different layers of the soil and the effect of manuring and cropping on it. The present investigation was undertaken to obtain information on this aspect.

Experimental

A series of nine permanent manurial plots, 20 ft. by 25 ft. each, was laid out in 1920 in the Pot Culture House Area of the Chemical Section at the old site of the Imperial Agricultural Research Institute at Pusa. Manures were applied to the plots once every year just before the monsoon. In these plots *ragi* (*Eleusine coracana*) was raised as the *kharif* (summer) crop followed by either wheat or oats as the *rabi* (winter) crop. Before the date of collecting soil borings in October, 1933, *ragi* was raised in these plots for 14 seasons, and wheat and oats for 2 and 11 seasons respectively. Nitrogen, phosphate and potash were applied singly or in combination as ammonium sulphate, superphosphate, and potassium sulphate respectively. In one of the plots mustard cake was applied. Three inches soil borings up to a depth of five feet were taken in October, 1933, from the above nine plots and also a fallow plot lying adjacent to them. Five representative spots were selected in each plot and 3-in. borings taken from each of them were composited for the purpose of analysis in this investigation.

In these soil samples calcium carbonate was determined by a simple method developed by the author [Das, 1944]. For easy reference it may be stated here.

The method consists in boiling for five minutes or agitating at intervals for half an hour at room temperature a known weight of soil with a measured quantity of half-normal hydrochloric acid solution, in slight excess of 4 to 5 c.c. and 50 c.c. of water, in a 500 c.c. conical flask and then titrating back the excess acid with decinormal caustic soda solution using phenolphthalein as indicator. The end point is very sharp and the titre figures are quite reproducible. One c.c. of N/2 HCl corresponds to 0·025 gm. of $CaCO_3$. The excess acid used in the process is diluted in the presence of 50 c.c. of water to about N/25 strength which is too dilute to have any appreciable secondary reactions with the soil complex, organic matter or soil bases. The close agreement obtained between the results of this process and those given by the standard gravimetric method in a large number of typical Indian soils reported in the paper cited lends support to the above contention. Therefore, the method has proved to be of sufficient accuracy to warrant its employment in routine soil analysis when a large number of samples have to be quickly tested.

For the sake of comparison all the carbonates in the soil are expressed in terms of $CaCO_3$ in Table I, although some of them may be attributed to $MgCO_3$.

TABLE I

The distribution of $CaCO_3$ at different depths of the fallow and the permanent manurial plots in Pusa calcareous soil

3-inch soil section	Depth in inches	Fallow plot	Plot 1 manure		Plot 2 Mustard cake		Plot 3 N+P+K		Plot 4 N+P		Plot 5 N+K		Plot 6 N+K		Plot 7 N		Plot 8 P		Plot 9 K	
		$CaCO_3$	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.
1 . . .	0—3	37·60	35·00		35·18		35·00		35·65		35·85		36·00		36·23		36·15		35·65	
2 . . .	3—6	37·08	35·43		35·40		35·48		35·68		36·35		36·43	Low	36·93	Low	36·43	Low	35·93	
3 . . .	6—9	36·93	35·50		35·23		36·00		36·00		37·03	Low	37·08		37·68		36·68		36·75	Low
4 . . .	9—12	36·43	35·40	Low	35·50		35·68		35·85	Low	36·43		37·23		38·23		37·15		36·50	
5 . . .	12—15	36·85	35·65		35·08	Low	36·85	Low	36·93		37·08		39·33		40·00		37·73	Medium	36·00	
6 . . .	15—18	36·88	35·15		35·75		37·50		36·73		37·85	Medium	38·00	Medium	40·23	Medium	39·35		38·43	Medium
7 . . .	18—21	37·68	35·08		36·00		37·25		35·90		41·00		38·65		40·85		43·50		40·93	
8 . . .	21—24	37·35	35·58		35·75		36·73		37·50	Medium	44·33		41·65		43·00		46·25		42·98	
9 . . .	24—27	38·00	36·55	Medium	35·75		37·25		39·50		45·98		45·00		16·00		46·85	Max.	44·35	Max.
10 . . .	27—30	38·48	38·00		37·58		38·00		44·55	Max.	47·50	Max	44·85	Max.	47·08	Max.	46·60		46·18	
11 . . .	30—33	38·75	42·85		39·40	Medium	39·35	Medium	45·23		46·60		47·00		46·25		47·25		44·75	
12 . . .	33—36	40·00	42·65		39·18		40·75		37·25		42·65		42·65		46·58		44·10		35·65	
13 . . .	36—39	38·75	43·50	Max.	40·50	Max.	41·23	Max.	31·50	Min.	30·48		33·68		38·93		32·25		30·93	Min.
14 . . .	39—42	39·75	42·75		42·50		42·50		30·65		30·43	Min.	31·93	Min.	30·50	Min.	33·50	Min.	30·50	
15 . . .	42—45	40·25	41·50		39·75		43·50		35·00		35·35		38·00		36·73		33·23		39·23	
16 . . .	45—48	40·58	38·85	Min.	35·90	Min.	37·25	Min.	40·15		43·98		40·43		46·85		45·18		45·23	
17 . . .	48—51	41·23	43·93		42·25		42·25		46·55		46·75		46·43		47·58		47·50		46·75	
18 . . .	51—54	41·33	45·85	Max.	45·23	Max.	45·58	Maxim.	44·50	Max.	45·25	Max.	45·00	Max.	44·93	Max.	11·58	Max.	14·25	Max.
19 . . .	54—57	42·50	42·93		43·18		42·23		43·50		44·75		46·75		46·25		45·50		45·23	
20 . . .	57—60	43·68	42·79		42·98		41·25		44·90		46·00		45·23		45·50		45·23		14·93	
Average $CaCO_3$ per 3-inch soil section		39·00	39·25		38·40		39·08		38·68		40·58		40·87		41·82		41·25	Mean	39·76 39·87	

In order to form an approximate idea of the distribution of $CaCO_3$ at different depths, the per cent average $CaCO_3$ per foot is stated in Table II. The average yields of *ragi*, wheat and oats raised in the plots before the soil boring was taken are given in Table III.

TABLE II

The per cent average $CaCO_3$ per foot of the fallow plot and the permanent manurial plots in Pusa calcareous soil

Per cent average $CaCO_3$ per foot	Plot No.	1	2	3	4	5	6	7	8	9
	Fallow plot	No manure	Mustard Cake	N+P+K	N+P	N+K	P+K	N	P	K
1st foot	37·01	35·33	35·33	35·54	36·80	36·42	36·69	37·27	36·60	36·21
2nd "	37·17	35·37	35·65	37·08	36·77	40·07	39·41	41·02	41·71	39·59
3rd "	38·81	40·01	37·98	38·84	41·63	45·68	44·88	46·48	46·20	42·73
4th "	39·83	41·65	39·66	41·12	34·33	35·06	37·51	38·25	36·04	34·97
5th "	42·19	43·88	43·41	42·83	44·86	45·69	46·85	46·09	45·70	45·29

TABLE III

Average grain yields in lb. of ragi (Eleusine coracana), *wheat and oats of the permanent manurial plots in Pusa calcareous soil*

Kind of grain	Plot No. 1	1	2	3	4	5	6	7	8	9
	Years averaged	No Manure	Mustard cake	N+P+K	N+P	N+K	P+K	N	P	K
Ragi .	14 : 1920 to 1933 .	3·94	16·47	16·61	15·92	14·39	8·07	11·51	6·18	3·93
Wheat .	2 : 1922-23 to 1923-24	4·38	6·06	6·38	6·09	7·68	7·63	5·91	5·56	4·88
Oats .	11 : 1920-21 to 1923-33, except above two years.	7·95	14·37	13·22	11·96	10·42	11·02	8·10	8·93	6·95

From Table II it is seen that in the six plots numbering 4 to 9 there are two zones of maximum carbonate concentration at third and fifth foot with an intermediate zone of minimum carbonate concentration at the fourth foot. Such distribution of carbonate is apparently absent in the remaining four plots. In them a gradually increasing concentration of carbonate seems to occur from the surface downward. Here the intermediate layer of minimum carbonate concentration is masked while taking the average carbonate content per foot. On a closer examination, however, of the individual data of carbonate concentration at different depths in Table I, similar zones are found to be the characteristics of all the cropped plots. The fallow plot, on the other hand, forms an exception where a gradual rise in carbonate concentration occurs from the surface downward with of course very insignificant fluctuations in the 2nd to 6th, and 13th and 14th layers which are within experimental errors. This plot was never cultivated nor manured and so represents the undisturbed soil.

In Table I the zones of carbonate concentration are classified into four broad divisions in all the permanent manurial plots, such as : (1) low, (2) medium, (3) maximum, and (4) minimum. There are two zones of maximum carbonate concentration with one of minimum concentration lying between them in every cropped and manured plot including the no-manure plot. Above them there are two zones of low and medium carbonate concentrations. The first three plots numbering

1 to 3 have their zones of minimum carbonate concentration at the 16th layer from 45 to 48 inches. These three plots may thus be placed in one group for comparison. Of these, however, the two manured plots, 2 and 3, behave similarly and have all zones of $CaCO_3$ concentration absolutely identical, whereas the no-manure plot 1 has the upper three zones located slightly differently, although the lower two zones are identical with those of the other two plots. Hence the no-manure plot has been included in this group with this reservation.

In the remaining six plots numbering 4 to 9 the area of minimum $CaCO_3$ concentration extends from 9 to 12 inches. Of these, the plots numbering 4 and 9 have an area of 12 inches each from 12th to 15th layers, and the rest 9 inches each from 13th to 15th layers. These plots thus differ from the previous group of three plots numbering 1 to 3 in having wider areas of minimum carbonate concentration with considerable shifting of three upper zones except the lowest maximum $CaCO_3$ zone which extends from the 16th to 20th layer in all the six plots. These may, therefore, be placed in a separate group.

That this classification of the nine cropped plots into two groups, namely, (I) the plots numbering 1 to 3, and (II) those numbering 4 to 9, is justified by the experimental evidence detailed in Table I, will be obvious on further scrutinizing the similarity of minimum and maximum $CaCO_3$ values of the soil horizons in the two groups of plots as set forth in Table IV.

TABLE IV

Similarity of minimum and maximum $CaCO_3$ values of the two groups of plots

Group	Plot No.	Per cent $CaCO_3$ in 3 in. soil layers	
		Minimum	Maximum
	Fallow	36·43	43·68
I	1 2 3	35·00 35·18 35·00	45·85 45·23 45·58
	Average	35·06	45·55
II	4 5 6 7 8 9	30·65 30·43 31·93 30·50 32·25 30·50	46·55 47·50 47·00 47·58 47·50 46·75
	Average	31·04	47·15

From Table IV it is seen that the two groups of plots numbering 1 to 3 and 4 to 9 are quite distinct in behaviour with respect to their individual minimum and maximum $CaCO_3$ values. As for example, these values vary between 35·1 and 45·6 in group I and 31 and 47·2 in group II on the average, whereas they vary between 36·4 and 43·7 in the fallow plot which shows no similarity with either of the above two groups of the treated plots.

In the same way, the zonal distribution of $CaCO_3$ shown in Table I clearly indicates the distinct behaviour of these two groups of plots, both of which stand on a footing quite different from the fallow plot. In the latter, the $CaCO_3$ content gradually rises from the surface downwards with very insignificant variations here and there which are quite unlike its pronounced fluctuations in all the other plots.

This phenomenon singles out the fallow plot from all the rest where the unequal vertical distribution of $CaCO_3$ resulting from the differential action of manuring and cropping over a number of years is quite remarkable. On the other hand, this gradually rising $CaCO_3$ concentration with

depth in the fallow plot has virtually remained almost intact, being not at all affected by the action of fertilizers, cropping and other cultural operations as in the case of the treated plots. This condition, therefore, represents the original profile characteristic of this fallow plot as well as of the entire adjacent area where the nine other plots were initially laid out for permanent manurial experiments in 1920. Since then 27 crops (Table III) were raised for 14 years in these plots after manuring every year before different depth samples were collected from them in 1933 for the present investigation. Although the original profile characteristic as well as the mechanical composition of all these plots including the fallow plot in their several soil horizons might be considered to remain more or less the same in 1920, the year of initiating the manurial experiments, subsequent changes were gradually brought about during the following years in the soil texture of the different horizons of the treated plots by the unequal movement of $CaCO_3$ due to the differential action of manuring, cropping and other cultural operations. As a result, the proportion of $CaCO_3$ in the soil horizons varied from 35 to 48 per cent in them as against 37 to 44 per cent in the fallow plot and exhibited quite irregular rise and fall in its concentration in different horizons as shown in Table I. It is, therefore, primarily the proportion of $CaCO_3$ which preponderates over other soil particles and materially affects the fluctuations of soil texture in different soil horizons, as will be shown in the sequel (Table VI), irrespective of the fact that the proportion of the ultimate soil particles, or for the matter of that, the mechanical composition of different soil horizons may remain more or less the same, when calculated on the soil residues left after the elimination or destruction of $CaCO_3$. Moreover, the proportion of ultimate soil particles is not liable to such irregular fluctuations as that of the fleeting substance like $CaCO_3$ due to the action of manuring and cropping, and will therefore remain almost at the same level in the control (fallow) and the treated plots. The fluctuation of $CaCO_3$ status and not the proportion of ultimate soil particles is thus primarily responsible for varying the texture of different soil horizons.

Considering further the data in Table I, it is found that the upper zone of maximum carbonate concentration occurs from 30 to 45 inches downward in the no-manure plot 1 and 36 to 45 inches in the manured plots numbering 2 and 3, whereas the same is found from about 18 to 24 inches downward in the rest of the treated plots. This shows the accumulation and concentration of carbonate nearer the surface in plots 4 to 9 than in the first three plots. In the latter group I the no-manure plot 1 has the upper zone of maximum $CaCO_3$ concentration starting from six inches higher layers than the manured plots 2 and 3; but in the next two lower zones all the three plots behave similarly. Therefore, the leaching of carbonate from the upper layers has taken place deeper in the plots 1 to 3 than the plots 4 to 9. This is brought about by rain-water dissolving CO_2 evolved from the respiration of plant roots. The CO_2 in the presence of water reacts on $CaCO_3$ and forms soluble calcium bicarbonate which leaches down into the deeper soil layers unlike the insoluble $CaCO_3$. The bicarbonate, however, eventually decomposes into CO_2 and $CaCO_3$. The latter is deposited increasing its concentration in the lower layers.

The solvent action of different fertilizer salts applied singly or in combination and also of mustard cake on $CaCO_3$ of the soil must be different. Further, the effect of these fertilizers on crop production in the differently manured plots is also different as detailed in Table III. This difference in crop production will obviously reflect on the proportions of CO_2 evolved from the respiration of plant roots and its consequent solvent action on $CaCO_3$. It is, however, difficult to differentiate between the rates at which the $CaCO_3$ is rendered soluble in the different plots by the solvent action of fertilizer salts and that of CO_2 produced by the respiration of plant roots under the soil conditions, where the reacting substances are static and where the volume and the rate of movement of water are comparatively small. Therefore, the solubility of $CaCO_3$ is not identical at different depths of the various plots from the operation of both these factors as evidenced by their varying $CaCO_3$ concentration. Thus the classifications of the treated plots into two groups is conditioned by the unequal $CaCO_3$ concentration due to the cummulative effect of these two factors and other cultural operations rather than the grounds of different crop yields alone which are not liable to easy differentiation. Fig. 1 demonstrates the varying $CaCO_3$ concentrations of these two groups of treated plots. In the no-manure plot 1, of course, cropping and other cultural operations except manuring have

effected the distribution of $CaCO_3$ in different layers. On the other hand, the fallow plot shows an increasing $CaCO_3$ concentration with depth. This gives a true picture of the carbonate status of the soil *in situ* which has not been disturbed by any external agencies, such as cultivation, manuring or cropping. Here the solubility of $CaCO_3$ is the least and therefore the variation in $CaCO_3$ concentration at different depths is at a minimum. The extent of the solubility effect in the various plots is graphically shown in Fig. 1.

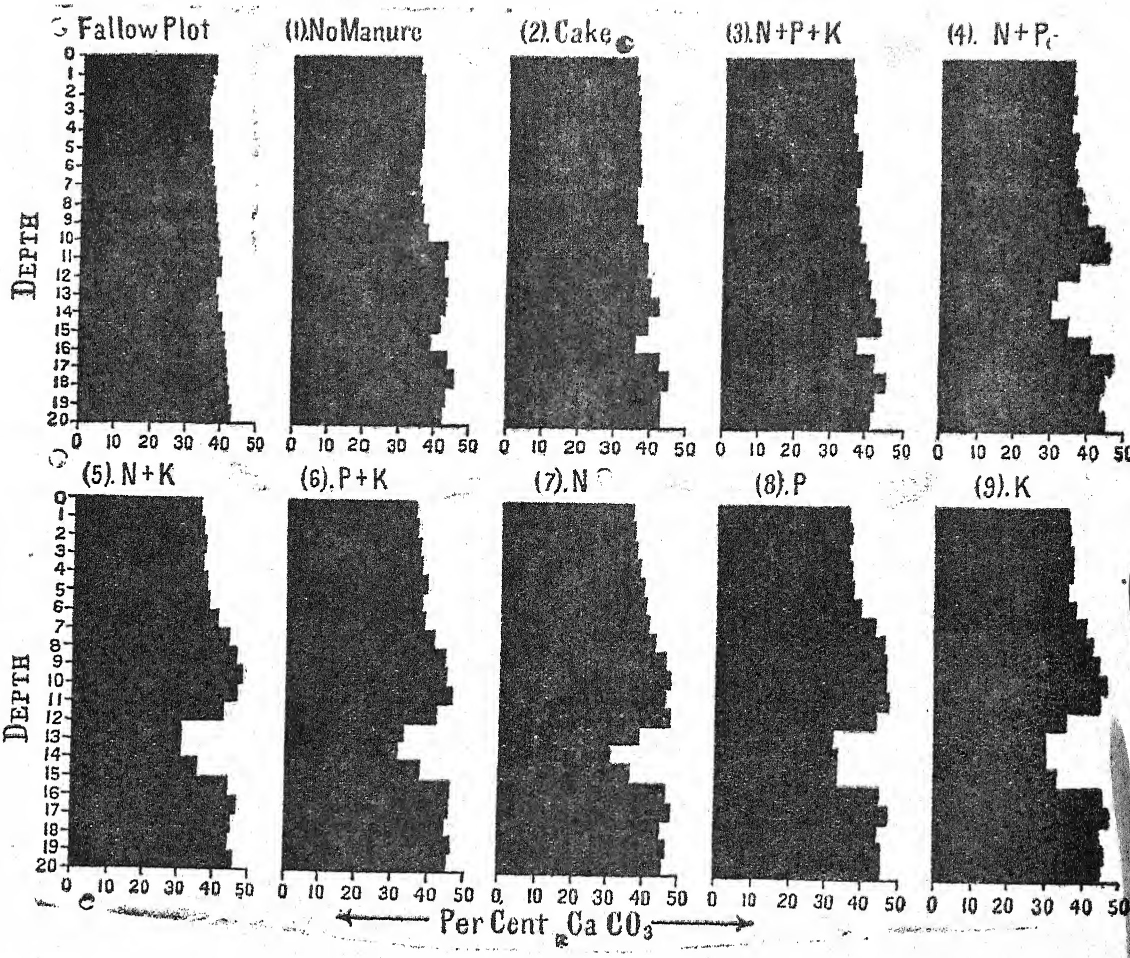

FIG. 1. The concentration of $CaCO_3$ at different depths of the fallow and the permanent manurial plots in Pusa calcarious soils

Taking the average of all the depths, it is seen in the last row of Table I that the mean percentages of $CaCO_3$ per depth of three inches are fairly constant in the different plots. Slight variations noticed are not significant at all and are obviously due to the accumulated experimental errors involved in 20 estimations in each case and also to the variation in the specific gravities of different soil horizons, for which no allowance has been made. It may, therefore, be concluded that the total $CaCO_3$ content of the soil up to a depth of five feet remains practically steady. It does not appreciably leach beyond five feet, but distributes itself in a characteristic way from layer to layer within this depth due to its differential solubility according as several fertilizer salts are applied singly or in combination and produce thereby varying crop yields in different plots.

Regarding the concentration of $CaCO_3$ at different depths of the various plots, it is noticed that there are two maxima and one minimum in every manured and cropped plot including also the no-manure plot with cropping, but none in the fallow plot which shows a continuously rising gradation of $CaCO_3$ indicating the absence of factors operating in the other plots. Plots numbering 1 to 3 and 4 to 9 form two distinct groups in their having characteristic zones of carbonate concentration with definite positions of their own. This is clearly demonstrated in Fig. 2. The data of plots (1) and (3), as well as (6) and (9) produce two distinct groups of graphs with characteristic maxima and minima. As the graphs from the rest of the plots fall into either of these groups, they are not reproduced in that figure to avoid overcrowding.

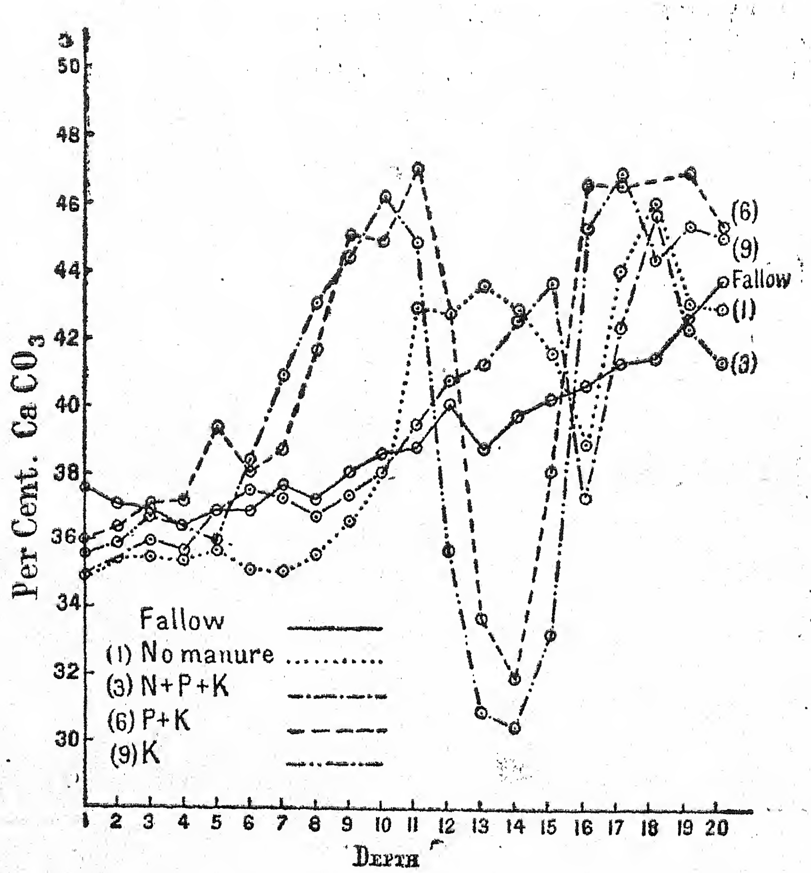

FIG. 2. The concentration of $CaCO_3$ at different depths of the two proups of the permanent manurial plots in Pusa calcareous soil

When these two groups of graphs are compared with the curve of the fallow plot, the pronounced effect of manuring and cropping on the movement of $CaCO_3$ in calcareous soils is made evident. Of course, the no-manure plot 1 shows only the effect of cropping on the vertical distribution of $CaCO_3$.

No lime or chalk concretions were encountered in any layer of the plots, while taking the soil borings. Chalk concretions are however formed as a perennial product in the bed of the river Gandak which flows by and surrounds the Pusa Estate almost on three sides. A sample of such concretions collected from the river bed gave the composition shown in Table V.

TABLE V

The chemical composition of chalk concretions collected from the bed of the river Gandak at Pusa

Constituents	Per cent
Loss on ignition	0·69
Silica and insoluble matter	37·21
Ferric oxide	3·11
Alumina	3·13
†Lime	29·56
Magnesia	1·80
Potash	0·28
Soda	0·33
Sulphate, SO_3	*Nil*
Phosphate, P_2O_5	0·07
* Carbon dioxide	23·22
	99·40
Undetermined	0·60
TOTAL	100·00
* Equivalent $CaCO_3$	52·83
† Calculated $CaCO_3$	52·78

It is seen from Table V that practically the whole of the carbonate present occurs in the form of $CaCO_3$ and constitutes about 53 per cent of the chalk concretions. The maximum amount of $CaCO_3$ encountered in the present inquiry was about 48 per cent in the Pusa calcareous soil within a depth of five feet which is only 5 per cent lower than the $CaCO_3$ content of chalk concretions. Its concentration may be higher in the still deeper soil layers.

The colour of the different layers of soil is grey and does not exhibit any marked difference with varying carbonate concentration.

The mechanical composition or rather the proportion of ultimate soil particles in the different soil horizons being not liable to much fluctuation due to manuring and cropping as the fleeting substance like $CaCO_3$, the changes in the soil texture will primarily depend upon the proportion of $CaCO_3$. So an attempt was made to discover if any relationship existed between the carbonate content of different soil layers and the soil texture as typified by moisture equivalent determined by the method of Briggs and McLane [1910]. The moisture equivalent is ordinarily taken to be the means of an indirect measurement of soil texture or mechanical analysis.

Out of ten plots which were examined for carbonate content, only two plots numbering 4 and 9, which were manured with N+P and K respectively, were chosen for the determination of moisture equivalent. The results are set forth in Table VI.

TABLE VI

The relationship between the moisture equivalent of different soil layers of Pusa calcareous soils and their varying calcium carbonate contents

3-inch soil sections	Depth in inches	Plot No. 4— N+P		Plot No. 9. K	
		$CaCO_3$ per cent	Moisture equivalent per cent	$CaCO_3$ per cent	Moisture equivalent per cent
1	0—3	35·65	14·25	35·65	15·08
2	3—6	35·68	15·00	35·93	16·17
3	6—9	36·00	14·73	36·75	18·33
4	9—12	35·85	15·93	36·50	19·42
5	12—15	36·93	16·33	36·00	18·58
6	15—18	36·73	16·28	38·43	8 00

TABLE VI—*contd.*

The relationship between the moisture equivalent of different soil layers of Pusa calcareous soils and their varying calcium carbonate contents

3-inch soil sections	Depth in inches	Plot No. 4. N+P		Plot No. 9. K	
		$CaCO_3$ per cent	Moisture equivalent per cent	$CaCO_3$ per cent	Moisture equivalent per cent
7	18—21	35·90	14·25	40·93	18·17
8	21—24	37·50	15·87	42·98	18·58
9	24—27	39·50	20·57	44·35	22·00
10	27—30	44·55	22·67	46·18	23·00
11	30—33	45·23	22·00	44·75	21·50
12	33—36	37·25	15·92	35·65	13·83
13	36—39	31·50	11·92	30·93	9·33
14	39—42	30·65	12·50	30·50	10·92
15	42—45	35·00	14·08	33·23	12·67
16	45—48	40·15	18·67	45·23	25·33
17	48—51	46·55	23·08	46·75	24·76
18	51—54	44·50	20·33	44·25	22·50
19	54—57	43·50	19·00	45·23	22·92
20	57—60	44·90	20·25	44·93	23·75

It is seen that there is a fairly direct proportionality between the carbonate content and the moisture equivalent of different soil layers. No such relationship was however observed by McMiller

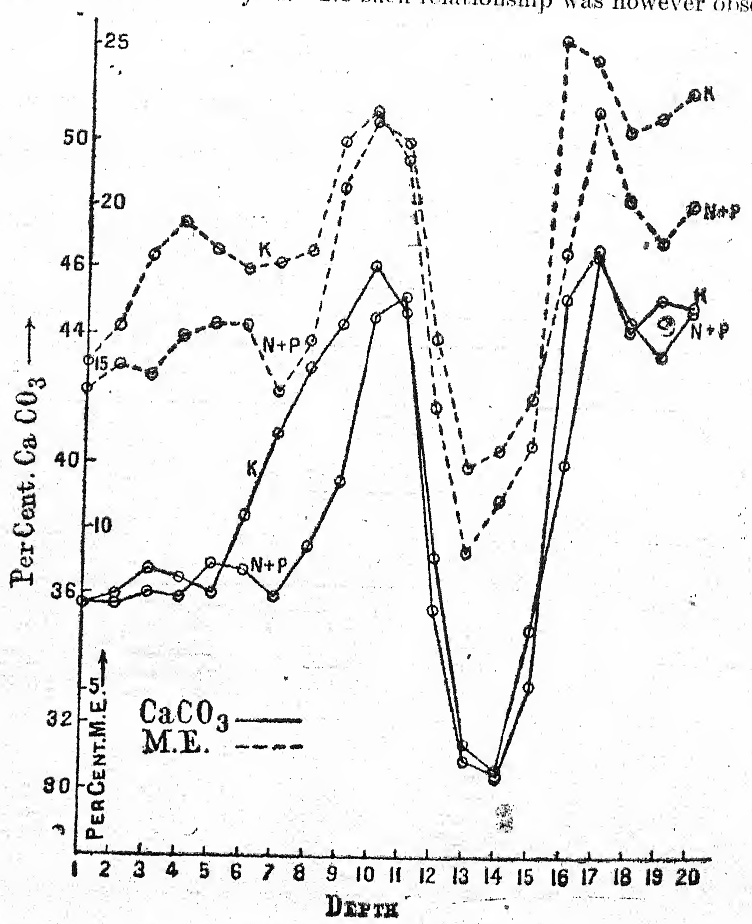

FIG. 3. The relation between $CaCO_3$ and moisture equivalent of different layers of Pusa calcareous soils

[1926] while examining two Minnesota calcareous soil types. The relation in the present instance can be better noticed in Fig. 3, where the percentages of $CaCO_3$ and moisture equivalent of different soil layers are plotted against the corresponding depths.

It is seen that the curves of $CaCO_3$ and moisture equivalent for calcareous soils of the two plots run almost parallel, showing a fairly direct relationship between the two. That is to say, the proportion of $CaCO_3$ regulates the texture of different soil horizons as typified by their moisture equivalent. Lower moisture equivalent will generally mean coarser texture and better permeability. Therefore, under natural soil processes greater leaching out of $CaCO_3$ and consequent lower contents of lime in these layers would be expected. This is what has actually taken place in plots 4 and 9 in 33 to 48 inches and 33 to 45 inches layers respectively which have the lowest range of $CaCO_3$ and moisture equivalents. The fact that the increasing amount of $CaCO_3$ in a calcareous soil beyond a certain limit acts as an inert substance like sand and helps in the mechanical opening of the soil, thereby improving its physical texture with the concomitant decrease of its moisture-holding capacity was demonstrated by the author long ago [Das, 1931].

Incidentally, the effect of manuring and cropping on the soil reaction was studied. Five permanent manurial plots and the adjoining fallow plot were included in this study. The results are given in the Table VII.

Table VII

The effect of manuring and cropping on the reaction (pH) of Pusa calcareous soils

3-inch soil sections	Depth in inches	Fallow plot	Plot 1 No-manure	Plot 2 Mustard Cake	Plot 7 N	Plot 8 P	Plot 9 K
		*p*H	*p*H	*p*H	*p*H	*p*H	*p*H
1 . . .	0—3	7·83	7·80	7·84	7·83	7·74	7·90
2 . . .	3—6	7·85	7·87	7·86	7·76	7·78	7·90
3 . . .	6—9	7·91	7·90	7·91	7·91	7·77	7·95
4 . . .	9—12	8·00	7·92	7·91	7·89	7·92	8·00
5 . . .	12—15	8·00	7·97	7·94	7·93	7·95	8·00
6 . . .	15—18	8·01	7·95	7·94	7·84	7·87	7·99
7 . . .	18—21	7·98	8·00	7·95	7·90	7·97	7·96
8 . . .	21—24	7·94	7·97	8·00	7·90	7·91	7·99
9 . . .	24—27	7·84	7·95	7·96	7·86	7·90	7·98
10 . . .	27—30	7·95	7·95	7·96	7·83	7·91	7·99
11 . . .	30—33	7·95	7·93	7·99	7·86	7·90	7·89
12 . . .	33—36	7·92	7·87	7·97	7·91	7·91	7·95
13 . . .	36—39	7·85	7·87	7·94	7·84	7·91	7·84
14 . . .	39—42	7·82	7·92	7·93	7·78	7·90	7·80
15 . . .	42—45	7·86	7·93	7·93	7·83	7·74	7·83
16 . . .	45—48	7·93	7·92	7·93	7·76	7·72	7·93
17 . . .	48—51	7·90	7·99	7·92	7·87	7·86	7·95
18 . . .	51—54	7·85	7·98	7·94	7·90	7·84	7·92
19 . . .	54—57	7·89	7·95	7·95	7·86	7·86	7·95
20 . . .	57—60	7·92	7·91	8·00	7·89	7·97	7·96

From Table VII it is evident that there is no appreciable difference in *p*H at the various depths of the differently-treated plots. It shows that the high proportion of $CaCO_3$ preponderates over all other soil constituents and rules the reaction of calcareous soils. It does not permit any variation of the reaction in spite of continuous manuring and cropping every year.

Summary

Three inches soil borings up to a depth of five feet were taken of nine permanent manurial plots and an adjacent fallow plot in Pusa calcareous soils. The concentration of $CaCO_3$ of these different soil layers was determined by a simple method developed by the author [Das, 1944].

It has been found that there are two zones of maximum carbonate concentration with one of minimum concentration lying between them in every manured and cropped plot, including also the no-manure plot. Above them there are two more zones of low and medium carbonate concentrations.

The fallow plot forms an exception where a gradual rise in carbonate concentraction occurs from the surface downward. This plot was never cultivated nor manured.

The differential effect of fertilizer salts as well as cropping on the movement of $CaCO_3$ in the differently-manured plots has been discussed.

The total content of $CaCO_3$ of these calcareous soils up to a depth of five feet remains practically constant. It does not leach beyond five feet, but distributes itself in a characteristic way from layer to layer within this depth due to its solubility according as different fertilizer salts are applied singly or in combination and produce varying crop yields in different plots.

The colour of the different soil layers is grey and does not show any marked difference with varying carbonate concentration.

There is a fairly direct proportionality between the carbonate content and the soil texture as typified by moisture equivalent.

The reaction (pH) of calcareous soils is unaffected by manuring and cropping owing to their dominant $CaCO_3$ content.

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THE BIOLOGICAL DECOMPOSITION OF GREEN MANURES

III. THE CHEMICAL CHARACTER OF HUMUS IN COMPOST HEAPS

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THE chemistry of humus has been the subject of attack for the last 150 years. The nature of the organic residues and the conditions under which they decompose chiefly influence the chemical nature of humus.

Several attempts were made since 1880 to synthesize humus but without success. These attempts have been reviewed by Waksman [1926]. Deherain [1888] was the first to indicate that humus may be a mixture of lignin and protein. This idea coupled with other observations, viz. (i) interaction of tannin-phenolic bodies like lignin with protein leading to the formation of 'humic bodies' [Moeller, 1916], and (ii) the average chemical composition of organic matter of soils [Waksman, 1929 and Waksman and Stevens, 1930], 78 per cent of which accounted for the two constituents like lignin and protein, led to the successful solution of this important problem, almost simultaneously but independently by Hobson and Page [1932] and Waksman and Iyer [1933]. Although these workers have established the constituents of synthetic humus they have not been able to show the proportion in which the two important constituents are linked together in natural or synthetic humus. The work described here reveals the proportion in which the lignin and the protein are present in humus by working directly with composts.

Degree of humification by hydrogen peroxide, though a crude measure, is still a useful guide to the amount of humification both in composts and soils in the absence of any quick and suitable method. Carbon and nitrogen ratios of the raw material and finished composts are no doubt most reliable but this determination is expensive and takes time and hence is not quite suitable for routine application. So far no comparative study of the two methods appears to have been made chiefly in respect of organic matter in composts.

If hydrogen peroxide removes all the humified organic matter and if humus is a ligno-protein complex as suggested by the above workers then almost all the lignin of the humic fraction should be removed during oxidation with peroxide. That a certain fraction of protein in the soil organic matter resists the action of peroxide beyond a certain strength is known from the work of McLean [1931]. Whether such a thing occurs in a compost is yet to be studied. It was therefore decided to conduct lignin and nitrogen determinations of the peroxide-treated compost in addition to the carbon and nitrogen ratios as on the untreated ones. These observations will give a comparison between the C : N ratios of the ligno-protein complex and the degree of humification. A study of the C : N ratio of the fresh material and compost and also of the oxidized material and the degree of humification may give an approximate estimate of loss of organic matter in a compost heap during fermentation for which there is no satisfactory method available at the moment. The C : N ratio and the lignin content of the residue after peroxide extraction will throw some light on the nature of the resistant material. If the lignin content be appreciable with a wide C : N ratio the residual material may resist further decomposition unless some available nitrogen and carbohydrates may be added for the requirements of the microflora.

Experimental methods

All the composts analysed in this paper were manufactured on the various Ceylon tea estates. They were dried at 100°C. powdered and sieved through a 64-mesh sieve for all the following analytical determinations :

(1) *Lignin.* This was determined on the hydrolysed product with 5 per cent H_2SO_4 for one hour as recommended by Norman and Jenkins [1934]. The hydrolysed product was then treated overnight with cold 72 per cent sulphuric acid. Volume was then made up to 800 c.c. with water and this was boiled for two hours.

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(2) *Extraction with peroxide.* The method employed was described by Shrikhande [1933]. The strength of peroxide used was 3 per cent.

(3) *Extraction with water.* Two grams of the material were extracted with the same volume of water and for the same length of time as with peroxide.

(4) *Total nitrogen.* Was determined by the usual Kjeldahl method.

(5) *Organic carbon.* Was estimated by the Robinson, McLean and Rice William method [1929].

(6) *Water and peroxide soluble constituents.* These were determined by evaporating to dryness the extracts on a water bath.

Results and discussion

1. *Carbon and nitrogen ratios of composts*

These ratios are presented in Table IA. All the composts examined have on an average a standard ratio of 12 :1 with the exception of the Gona Adika. The variation in the C and N values of different composts is apparently due to the difference in the nature of fermentable materials used on different estates.

TABLE I

Carbon : nitrogen ratios of composts, of their residues on peroxide treatment and of the peroxide soluble fraction

(Results expressed on 100 gm. of original compost)

Compost	C : N ratios of composts A			C : N ratios of residues B			C : N ratios of soluble fractions C		
	C	N	C/N	C	N	C/N	C	N	C/N
Galha	20·00	1·46	13·7	10·80	1·08	9·8	9·20	0·38	24·2
Ensalwatte	10·84	0·93	11·6	4·22	0·36	11·6	6·62	0·57	11·7
Beaumont	9·66	0·63	15·3	4·48	0·32	13·9	5·18	0·31	16·8
Rye	18·12	1·07	16·9	13·70	0·47	28·7	4·42	0·60	7·4
Gona Adika	32·68	4·42	7·4	15·82	1·90	8·3	16·86	2·52	6·7
Lethenty	14·70	1·09	13·5	3·80	0·26	14·6	10·90	0·83	13·1
Lethenty (dry compost)	26·64	1·75	14·9	6·58	0·46	14·3	19·56	1·29	15·1
East Holy	12·47	0·98	12·7	2·11	0·23	9·1	30·36	0·75	13·9
Tanagakelle	12·50	1·04	12·0	2·48	0·33	7·7	10·02	0·71	14·0
Wikiliya S24·2	19·69	1·75	11·2	8·74	0·52	17·3	10·64	1·23	8·7
„ S39·7	20·94	1·26	15·8	11·26	0·26	43·3	9·68	1·00	9·7
„ S39·9	25·24	1·62	15·5	12·21	0·43	28·2	13·03	1·19	11·0
„ S39·23	17·67	1·16	15·2	4·22	0·24	17·9	13·45	0·93	14·5
„ S40·1	12·92	1·12	11·5	4·84	0·22	21·8	8·08	0·90	9·0
Poonagalla A	13·81	0·94	14·7	..	..	..	..	..	..
„ B	16·93	1·35	12·5	..	..	..	..	..	..
Mahagastote 9	20·34	1·58	12·8	..	..	..	..	..	..
„ 11	23·91	1·50	15·9	..	..	..	..	..	..
„ 12	31·79	1·91	16·6	..	..	..	..	..	..

2. *Carbon : nitrogen ratios of residues on peroxide treatment of composts*

These ratios in Table IB are in general of the same order as the original composts with exceptions in Rye, Wikiliya S 39·7, Wikiliya S 39·9 and Wikiliya S 40·1. The uniformities in such ratios is due to the proportionate extraction of carbon and nitrogen by 3 per cent hydrogen peroxide. This means

in effect that the strength of peroxide employed was just sufficient to attack both carbon and nitrogen in a proportion without affecting the extra carbonaceous material. The work of McLean [1931] on soil organic matter has demonstrated that the strength of peroxide over 1·5 per cent removed a considerable amount of carbon leaving nitrogen almost unaffected, suggesting that carbon from cellulose or other carbonaceous material and not from the humus fraction was being attacked by higher concentration of peroxide than 1·5 per cent. This observation is significant in so far as it indicates a definite relationship between carbon and nitrogen of the soil humus. Such an analogy can very well be applied to composts, the only difference being that the strength of peroxide required for composts is double of that for soil humus. This should be expected because the concentration of humus in a compost is always greater than in a soil. Whether higher concentration of peroxide has an effect on carbon other than humus carbon is a matter of further enquiry. Provided the method is standardized with respect to the strength of peroxide and the period of heating, it can still serve as a useful guide to determine the degree of humification in composts.

The exceptions in Rye, Wikiliya S 39·7 and Wikiliya S 39·9 can be accounted for by the lower extraction of carbon but with Wikiliya S 40·1 although carbon was extracted slightly more than in any other compost, the nitrogen was extracted in still larger amounts. Such composts giving peroxide residues of a wider C/N may resist further decomposition and may not nitrify on account of their low nitrogen content.

3. *Carbon : nitrogen ratios of oxidized and dissolved portion of composts during peroxide treatment*

These ratios are based on the carbon and nitrogen found by difference between the two constituents in composts and residues left after peroxide treatment from Table IA and IB. The results are included in Table IC. The trend of ratios is the same on the whole like the original composts with the exception of Galha, Rye and Gona Adika. Gona Adika with the narrowest ratio continues to be an exception from the very beginning on account of the nitrogenous nature of the material used for composting.

On comparing the values for nitrogen attacked by peroxide with those in original composts in Table IA it is clear that nearly 60 per cent of the total nitrogen in composts has been rendered soluble. This value may be taken as the upper limit for the availability of nitrogen in composts as discussed in a previous communication [Shrikhande, 1945]. As the process by which such nitrogen has been extracted occurs in two stages, viz. (*i*) by mere solution as in water, and (ii) by oxidation with peroxide, it is reasonable to conclude that the nitrogen obtained purely by solvent action of this reagent should become easily available to the plant whereas nitrogen which is affected by the oxidizing action of peroxide should be rendered gradually available by the oxidation process in soil though not so readily as the former.

4. *Water soluble nitrogen and water and peroxide soluble constituents of composts*

The greater extractibility of and the different nature of peroxide extraction is clearly demonstrated by comparing the water soluble nitrogen in Table II with peroxide removable nitrogen in Table IC. The amount of nitrogen over and above that extracted by water is obviously due to the oxidizing action of peroxide besides its purely solvent action. These differences are indeed quite large and clearly indicate a specific action of peroxide on the nitrogen complex of a compost.

The availability of nitrogen should vary according to the amount and nature of nitrogen present in the original vegetable refuse. All the composts examined should easily nitrify when applied to the land if we take into consideration only the C : N ratios. What amount of nitrogen will actually become readily available from each compost is difficult to say unless each compost is subjected to nitrification tests. But viewing the results on the basis of water solubility and easily available nitrogen, it is possible to suggest that about 10 per cent of the nitrogen which is water soluble in these composts may quickly nitrify and thus become easily available to the plant. This value is one-third of what is given by composts obtained purely from green manures underlaboratory conditions [Shrikhande, 1945].

TABLE II

Water soluble total nitrogen and water and peroxide soluble constituents of composts

(Results expressed on 100 gm. of original compost)

Compost	Water soluble N	Water soluble fraction	Peroxide soluble fraction
Galha	0·12	7·68	16·78
Ensalawatte	0·07	2·85	13·78
Beaumont	0·06	2·65	8·28
Rye	0·09	4·93	18·93
Gona Adika	0·28	9·83	49·63
Lethenty	0·14	2·83	22·14
Wikiliya S24·2	0·09	5·93	28·65
" S39·7	0·10	4·18	24·70
" S39·9	0·10	8·58	31·15
" S39·23	0·12	6·05	23·58
" S40·1	0·11	4·00	26·40
" S40·2	0·25	6·78	29·00
Poonagalla A	0·06	2·68	..
" B	0·07	3·75	..
Mahagastote 9	1·24	11·32	23·43
" 11	0·20	6·75	29·04

5. *Organic matter content of original and peroxide treated composts and the degree of humification*

Organic matter in compost depends upon the type of material and the mineral matter introduced during composting. At times lot of mineral matter in the form of soil is introduced either with the stubble or at the time of turning the heap which contributes essentially to a low organic matter content of compost and consequently there is a poor recovery of humified matter. This can clearly be noted in Beaumont compost where the initial organic matter and the humified material is the lowest of all the composts reported in Table III. The other extreme is the extremely high original organic matter content with an excellent degree of humification of 78 per cent in the Gona Adika compost. This may be the maximum limit of humification expected in compost manufactured on a large scale.

Taking into account the heterogenous nature of material utilized on various estates it is interesting to note that the organic matter content of most of the composts tested approximated to an average of 45 per cent and the degree of humification to about 60 per cent. By comparing the degree of humification with C : N ratios of composts in Table IA, it can be seen that the highest humified compost on Gona Adika has the narrowest C : N ratio whereas the lowest humified compost on Rye estate has the widest ratio. A relation therefore seems to exist between the degree of humification and the C : N ratios. The average ratio of 12 : 1 may be taken as equivalent to about 60 units of humification. A compost manufactured from a material of an average composition which is fermented for a period of three months usually suffers a loss of 30 to 40 per cent in dry matter. Such a loss brings down the ratio in the proximity of 12 : 1. Knowing therefore the degree of humification it may be possible to roughly predict the loss inorganic matter a compost had undergone during decomposition. From the above observation one unit loss of dry matter may be taken as equivalent to about two units of humification. It is rather difficult to put down any definite formula for assessing the loss of dry matter in compost heaps because of the absence of data for both the original amounts of material taken and the finished compost obtained therefrom.

Table III

Organic matter content of original composts, their residues on peroxide treatment and the degree of humification

(Results expressed on 100 gm. of original compost)

Compost	Organic matter in composts	Organic matter in residues	Organic matter humified	Degree of humification
Galha	37·60	11·68	25·92	68·9
Ensalwatte	22·00	14·43	7·57	34·4
Beaumont	15·24	14·07	1·17	7·7
Rye	42·29	35·26	7·03	16·6
Gona Adika	79·44	17·36	62·08	78·2
Lethenty	51·20	39·92	11·28	22·0
Lethenty (dry compost)	48·60	21·23	27·37	56·4
East Holi	27·03	11·21	15·82	58·48
Tanagakelle	41·79	14·00	27·79	66·5
Wikiliya S24·2	47·56	20·62	26·94	56·6
,, S39·7	47·24	26·36	20·88	44·3
,, S39·9	53·85	28·00	25·85	48·0
,, S39·23	38·34	13·22	25·12	65·4
,, S40·1	43·50	16·39	27·11	62·3
,, S40·2	44·06	15·62	18·44	41·9
Mahagastote 9	41·65	23·23	18·42	44·2

6. *Lignin content of original composts and of their residues after peroxide treatment*

Table IV includes percentage loss of lignin on peroxide extraction of composts in addition to the lignin of original composts and their respective residues. Looking at the last column of Table IV it is interesting to note that 60 per cent of lignin in composts has been removed by peroxide treatment with the exception of Tanagakelle. Since hydrogen peroxide does not appreciably affect the lignin content of any plant material, it appears therefore reasonable to presume that the lignin in the original plant materials has been transformed into such a form as to be liable to attack by peroxide. The transformation which is the most likely one is its conversion to humus in association with the protein synthesized by the micro-organisms during the process of decomposition. An indication of such an association is obtained by definite proportionality between the extraction of carbon and nitrogen by the peroxide as shown in Table 1A and 1B. This is suggestive of the lignin-protein nature of compost humus.

A certain proportion of lignin has resisted the attack of peroxide. This fraction may either be still present in its native state, i.e. it was unaffected during fermentation and thus could not combine with the micro-organic protein to form humus, or that the strength of peroxide was not sufficient enough to attack this fraction of lignin. The former seems to be the chief possibility in so far as it is known that the process of composting although rapid in the first few days slows down considerably after about 50 per cent of dry matter has been lost. This view has been confirmed by the recovery of cellulose and other structural constituents from fermented vegetable materials. The strength of hydrogen peroxide has been shown to be just sufficient for the attack of humified material in compost as pointed out in section 2.

TABLE IV

Lignin content of original compost and their residues on peroxide extraction
(Results expressed on 100 gm. of original compost)

Compost	On original compost	On residue	Percentage of loss of lignin peroxide treatment
Galha	19·50	11·24	42·36
Ensalwatte	11·04	4·57	58·61
Gona Adika	35·99	2·27	93·67
Lethenty	16·11	4·94	69·31
Lethenty (dry compost)	26·68	10·01	62·47
East Holi	11·37	3·21	71·78
Tanagakelle	11·87	11·47	3·37
Wikiliya S24·2	19·73	9·21	53·01
,, S39·7	20·44	3·99	80·48
,, S39·9	27·32	12·87	52·89
,, S39·23	16·40	5·35	67·40
,, S40·1	17·60	5·23	70·28
,, S40·2	21·28	5·68	73·31
Mahagastote 11	21·11	5·09	75·88
,, 13	39·50	20·65	47·55

7. *Lignin-nitrogen relationship in the peroxide removable fractions and also in the residues after peroxide treatment of composts*

Having obtained indications of the lignin-protein nature of humus by working directly with natural humic bodies in composts it was thought desirable to work out the proportions, if possible, of the two important constituents of the humus nucleus from the data in hand. Although it would have been more convenient to obtain such relationship in terms of lignin and protein as done by Hobson and Page [1932] and Wakesman and Iyer [1933], it was thought desirable to restrict consideration to lignin-nitrogen relationship for two reasons, viz. (1) the protein conversion factor of 6·25 is purely arbitrary, and (2) the nitrogen present in the vegetable material from which these composts were manufactured was not entirely of a protein character. All the composts manufactured on tea estate usually contain an appreciable amount of refuse in the form of tea leaf prunnings and refuse tea. These materials contain about 25-30 per cent of their total nitrogen in a non-protein form as caffein. Table V presents such lignin-nitrogen relationship in the humic and non-humic portions of composts.

TABLE V

Lignin-nitrogen relationship in the humic and non-humic fraction

Compost	Peroxide soluble fraction			Residue after peroxide extraction		
	Lignin	Nitrogen	Lignin / Nitrogen	Lignin	Nitrogen	Lignin / Nitrogen
Galha	8·26	0·39	21·5	11·24	1·08	10·5
Ensalwatte	6·47	0·57	11·4	4·57	0·36	12·6
Gona Adika	33·72	2·52	13·4	2·27	1·90	11·9
Lethenty	11·17	0·83	13·5	4·94	0·26	18·9
Lethenty (dry compost)	16·67	1·29	12·9	10·01	0·46	21·7
East Holi	8·16	0·75	10·9	3·21	0·23	13·8
Tanagakelle	0·40	0·71	5·5	11·47	0·33	49·4
Wikiliya S24·2	10·46	1·23	8·5	9·27	0·52	17·8
,, S39·7	16·45	1·00	16·4	3·99	0·26	15·3
,, S39·9	14·45	1·19	12·2	12·87	0·43	29·7
,, S39·23	11·05	0·93	12·0	5·35	0·24	22·8
,, S40·1	12·37	0·90	13·8	5·23	0·22	23·4
			Mean 12·58			*Mean* 20·65

Relative variance 0·0911 (*P*=0·05) *Relative variance* 0·2412 (*P*=0·05)

It will be noted from the ratios of lignin to nitrogen in the humified fraction that they are fairly constant, whereas there is a greater variation between such ratios in the case of residues after peroxide treatment or the non-humic fractions. On a statistical examination in terms of relative variances it is found that the difference between them is significant. It can thus be concluded that the humus nucleus consists of 12 parts of lignin to 1 part of nitrogen whereas the non-humic fraction has the ratio of the order of 20 : 1 for lignin to nitrogen. This non-humic fraction may resist further decomposition on account of its proportionately high lignin content. This may also resist nitrification in the soil. This clearly explains why decomposition considerably slows down after a certain amount of organic matter has been lost; an equilibrium is thus established between the humic and non-humic portions of composts.

Hydrogen peroxide has therefore proved a valuable reagent by which it became possible not only to throw light on the lignin-protein nature of humus but also to establish a quantitative relationship between the two important constituents of the humic nucleus. Another importance of these findings lies in the fact that these conclusions have been arrived at by working directly with natural humic substances such as composts rather than with artificial preparations obtained by the interaction of chemical reagents.

Summary

1. All the composts examined contain a suitable carbon-nitrogen ratio approximating to the standard of 12 : 1.

2. C : N ratio of the residues left after peroxide treatment are very close to those of original composts with a few exceptions. The C and N are thus extracted in a definite proportion by 3 per cent hydrogen peroxide without attacking the unhumified portion of composts. A relationship between the degree of humification and the C : N ratio of composts has been indicated. Provided the method of peroxide treatment is well standardized with respect to its strength and the time of extraction, it can still serve as a useful guide in determining the degree of rot in decomposed vegetable materials.

3. Hydrogen peroxide has been shown to extract more than water. Water extracted about 10 per cent of total nitrogen whereas peroxide removed about 60 per cent of nitrogen in composts. The limits of availability of nitrogen in composts have been discussed on the easily soluble and quick availability hypothesis. The range as shown by these experiments also lies between 20 per cent and 60 per cent obtained by the nitrification and crop recovery tests of other workers.

4. By the help of peroxide the organic matter of composts has been separated into fractions, viz. (1) humic, and (2) non-humic. The nature of humic fraction is the same as the soil humus. The C : Nratio of peroxide residues and the peroxide removable fraction coupled with the lignin estimations confirm the lignin-protein nature of humus nucleus. A quantitative relationship has also been established between the two important constituents. The lignin nitrogen ratio of the humic fraction is more or less a constant and approximates to 12 : 1 whereas there is a greater variation in the case of non-humic fraction and is of the order of 20 : 1.

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THE BIOLOGICAL DECOMPOSITION OF GREEN MANURES

IV. LOSS OF LIGNIN DURING AEROBIC FERMENTATION

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In view of several factors being involved in the decomposition and also in the determination of lignin in original and fermented materials different workers have reported different results even on similar materials. Tenney and Waksman [1929] in their studies on corn stalks, rye straw and oak leaves recorded definite losses of lignin but much less in proportion than of any other constituent. On the other hand, extensive decomposition of lignin under aerobic conditions was obtained by Philips, Wiehe and Smith [1930]. Their experiments were comparatively brief in duration and losses of lignin recorded were in some cases higher than those of cellulose. Several such conflicting views and data have been reported in the literature on the subject of decomposition of lignin. For a good review of the subject readers may refer to Norman [1936]. The subject being still controversial, a good deal of work is yet necessary to solve its intriguing nature by applying new methods which have recently been developed by Norman and Jenkins [1934] for the quantitative determination of lignin. In this paper are recorded some data on the subject of lignin decomposition in various materials including nearly half a dozen tannin materials.

Methods and results

The various plant materials were fermented aerobically in bottles as described in Parts I and II of this series [1945, 1946]. The dried material was ground to pass through 64-mesh sieve before applying the Norman and Jenkin's method [1934] for lignin determination in non-tans and Shrikhande's method [1940/a] for lignin determination in tannin materials.

Table I contains results for both the type of materials rotted aerobically for periods upto six months. The losses of lignin obtained are somewhat similar to those recorded by Norman [1935] for oat straw fermented for a period upto 12 months. In non-tan materials the maximum loss of lignin sustained by sun-flower after six months was 26 per cent and the least loss of nearly 2 per cent by gravilleas. These losses of lignin appear to be in proportion to the losses of dry matter since sun-flower had suffered a loss of nearly 60 per cent in dry matter against hardly 15 per cent by gravilleas. On an average the non-tans investigated lost nearly one-fifth of their original lignin after six months' fermentation. Addition of mineral nitrogen did not affect the loss of lignin to any appreciable extent. This loss of lignin compares very poorly with losses of cellulose and hemicelluloses, which may amount to even 60 per cent in such a period of decomposition. It is apparent therefore that lignin is not so readily available to the micro-organism as cellulose and hemicelluloses. The tannin materials on the other hand show a very small loss of lignin in similar periods although losses of dry matter were normal. This exceptional behaviour of this class of materials may again be attributed to the antiseptic properties of tannins which might inhibit the growth of micro-flora responsible for the loss of lignin as in non-tanniferous species. This exceptional behaviour of tannin materials has been reported by the author on previous occasions [1940 a, 1940 b and 1946].

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TABLE I

Aerobic decomposition of lignin in various materials at 25°C. (Results expressed on the basis of original weight)

Material	Original lignin content per cent	Percentage of loss of lignin after—					
		5 weeks' decomposition			24 weeks' decomposition		
		Without mineral nitrogen	With $(NH_4)_2SO_4$	With $NaNO_3$	Without mineral nitrogen	With $(NH_4)_2SO_4$	With $NaNO_3$
Sun flower	25·83	9·38	10·96	11·31	22·39	24·38	26·00
Dadaps	29·24	7·05	7·35	7·31	21·33	22·54	23·23
Tephrosia	28·86	5·75	6·79	9·89	17·58	19·51	20·32
Gliricidia	22·34	9·93	12·05	10·07	15·31	16·07	17·18
Maana grass	18·45	5·69	8·95	13·27	18·11	18·54	18·71
Weeds	16·82	10·00	10·76	10·19	15·96	17·18	17·86
Grairlleas	33·15	0·42	1·21	1·96	0·76	1·21	1·96
Fern	28·56	12·05	13·21	15·81	17·18	19·82	21·[illegible]3
Cane reed	17·32	..	7·62	9·59	6·47	14·09	17·22
Paddy straw	15·23	..	8·41	12·08	7·62	16·29	20·51
Refuse tea	26·61	2·29	3·42	3·38	5·68	6·43	6·98
Tea leaf (Prunings)	23·93	3·47	4·63	4·93	8·02	8·36	9·12
Caesalpinia bonducella	23·85	3·06	..	..	4·61	..	..
C. sappan	17·70	4·58	..	..	9·59	..	..
C. coriaria	15·50	3·87	..	..	8·91	..	..
Terminalia belerica	23·70	2·53	..	..	7·00	..	..
Pterocarpus indicus	16·94	2·60	..	..	6·19	..	..

SUMMARY

Lignin determinations by Norman and Jenkin's method [1934] and Shrikhande's method [1940] for non-tanniferous and tanniferous species respectively indicate that lignin under aerobic conditions is by far the most resistant major constituent and suffers a small loss in a period of five weeks. This loss increases with longer periods amounting to nearly 20-25 per cent in six months. This is, however, only about one-third of the loss undergone by cellulose and hemicelluloses under similar conditions. In tannin materials losses of lignin are almost negligible and this may be attributed to the antiseptic properties of tannins which modify the micro-flora.

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CITRUS PROPAGATION STUDIES*

THE INFLUENCE OF DIFFERENT METHODS OF BUDDING, AFTER-TREATMENTS AND ROOTSTOCK VIGOUR ON BUD-BREAK, BUD-TAKE, HISTOLOGY OF BUD-UNION AND SIZE OF BUDLINGS IN CASE OF SWEET ORANGE, MANDARIN AND SOUR LIME

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(with Plates I and II)

MOST economic plants, including fruit trees, are propagated by vegetative means such as, grafting, budding, layerage and cuttage. The citrus trees, however, are propagated universally by budding and the method used is termed shield-budding or T-budding. It consists in inserting the bud of one tree, with a shield-shaped piece of bark, beneath the bark of another through a T or inverted T-shaped incision.

The scion-bud, as removed from the bud-stick, carries a thin slice of wood on its under surface but, before it is inserted beneath the bark of the root-stock, the slice of wood requires to be discarded according to some workers whereas others recommend its retension. The experience of most workers in India, England, Continent of Europe, New York (U. S. A.) and Palestine—[Sham Singh, 1938; Lorette, 1925; Feilden, 1936; Davis, 1922; Hall & Crane, 1933; Cheal, 1892; Kains, 1930; and Mendel, 1936] points to the view that the piece of wood, beneath the scion-bud, plays no part in facilitating its union with the stock but that, on the contrary, it may actually retard this process. Mendel [1936] says 'the older wood and pith are incapable of regeneration'. Thus, if the central core of wood in the 'shield' is not removed, the shield has to be cut away thin to allow callus to form on the entire cut surface. It follows that from a practical standpoint, the budding of citrus should be done 'without wood'. This is in accordance with the opinion of authors referred to above who recommend complete removal of wood from the bud before inserting it into the stock, but care has to be taken that, in doing so, the bud-germ is not damaged.

Most American writers [Auchter & Knapp, 1929; Budd, 1914; Bailey, 1903; 1920; Coit, 1915; Fuller, 1905; Green, 1911; Hume, 1909; Thomas, 1920; Wickson, 1926; Hansen, 1936; and Maynard, 1905], on the other hand, assert that the scion-bud should have a thin piece of wood attached to it when inserted into the root-stock. One English author [Baltet, 1910], and one Indian [Naik, 1939] also agree with the American view-point. Baltet [1910] says, 'there is no harm in leaving a small particle of wood under the bark of the bud-shield; it will help to render the union of the parts more intimate'. According to Bailey [1903-20] too 'the bit of wood probably serves a useful purpose in retaining moisture, but at the same time it interposes a foreign body between the two healing surfaces, for the bark of the bud units directly with the cambium of the stock'. In a recent study, carried out in India, Naik [1939] with meagre data concluded thus 'the superiority of inserting the bud with wood over the common Indian method of inserting the bud after removal of wood may be said to have been clearly established'. Under South African conditions, Powell [1930] does not appear to attach much importance to either method of budding as according to him 'it is largely a matter of individual experience'. Sham Singh [1938] corroborated, in general, the view held by Powell as, according to him, the difference in the two practices is conventional as with certain scions both methods gave equally good results in the Punjab. He has, however, suggested the adoption of the American method in case of grapefruit, sweet lime and sour lime, etc. where the Indian method does not work well due to the thorny nature of buds, although Cheema [1929] advises the production and selection of thornless shoots for propagating the sour lime. It is clear, therefore, that the horticultural investigators in different countries tested the suitability of the two methods of budding not only from the viewpoint of higher percentage of take of buds but also from the nature of union taking place between the scion and the rootstock.

* The present paper is a part of the thesis approved for the Degree of Master of Science in Agriculture in the University of the Punjab

The difference in the two practices lies not only in the removal and preparation of the scion-bud and the nature of the union taking place, but also in the way in which the stock seedling is treated after the bud is inserted. The technique followed in giving the 'after-treatment' or the way of treating the seedling top after inserting the bud varies considerably from country to country and even in different parts of the same country to suit either the individual preference or the conditions prevailing. Some believe in severing the stock top immediately after inserting the scion bud, others allow the stock top to remain intact till after the scion bud has united and still others prefer to give a half way cut to the stock top after inserting the scion bud. It is, however, commonly believed that these operations or 'after-treatments' play a considerable part both in the efficiency of bud-take and the proper development of bud sprouts.

It is obvious, therefore, that in testing the suitability of a particular method of budding, the after-treatment to be given should also be determined simultaneously for different kinds of fruits and different seasons of budding. With these aims in view, and also to study the nature and development of union between scion and stock and the influence of rootstock vigour on the size of budlings, citrus propagation trials were initiated in the nurseries of the Punjab Agricultural College, Lyallpur, early in the autumn of 1939 and continued till the middle of 1941.

Material used

Plots containing seedlings of rough lemon (*Citrus limonia* Osbeck), known locally as *jatti khatti* were selected in the nurseries of the Punjab Agricultural College, Lyallpur. The seedlings were growing in a uniform piece of land, which was loamy in nature and which received uniform cultural treatments ever since the seedlings were planted therein. Furthermore, the seedlings were of the same age and origin and were nearly two years old at the time of selection in autumn 1939. Notwithstanding all this, the seedlings differed considerably from one another with regard to height and thickness. Therefore, for the purpose of the trials reported here, seedlings of uniform vigour with considerably low coefficient of variability were selected as outlined in Table I.

Table I

The material used for various experimental trials

Serial No.	Season	No. of seedlings under experiment	Purpose of experiment
1	2	3	4
1	Spring 1940	504	Propagation trials with mandarin (*C. nobilis* var *deliciosa* Swingle)
2	Do.	504	Propagation trials with sweet orange (*C. sinensis* Osbeck)
3	Do.	84	The anatomy and histology of union between scion and rootstock
4	Summer 1940	558	Propagation trials with sour lime (*C. aurantifolia* Swingle)
5	Do.	240	Repetition of the propagation trials with mandarin
6	Do.	288	Repetition of the propagation trials with sweet orange
	Total	2,178	

Methods employed

Selection of seedlings and the methods of propagation studied

It is evident from Table I that 2,178 seedlings were finally selected for various trials reported here. To achieve this, about double this number was measured in the field for diameter (correct to the nearest millimeter) at nine inches above the ground level. It was thus possible to select seedlings of the required thickness and the rest, which were either too thick or too thin, were not budded.

After this, the selected seedlings were divided into different groups, based on diameter measurements and labelled accordingly. The propagation methods studied were the following:

(a) The Indian method of budding, in which case the scion bud did not carry any trace of wood on its under surface.

(b) The American method of budding, in which case the scion bud carried a thin slice of wood along with it on the under-side—the thickness of wood being in the neighbourhood of $\frac{1}{40}$ in.

(c) The practice of lopping the seedling top, immediately after budding, at about two inches above the inserted scion bud.

(d) The practice of delaying the cutting of the seedling top, above the inserted bud, till such time as the scion-bud growth was first noticed.

(e) The practice of notching the seedling top, on the side of inserted bud and two inches above it, immediately after budding but lopping the same, at the point of notch, after the scion-buds were seen sprouting.

For convenience of reference, the above noted five treatments will be denoted hereafter by B_1, B_2, P_1, P_2 and P_3 respectively.

Study of the union between scion and rootstock

With a view to see if the thin slice of wood, attached to the bud-shield, had anything to do with improper, delayed or defective union of the scion and rootstock, 84 seedlings were selected, half of which were budded by the Indian method using sweet orange and mandarin scions and the other half were budded by the American method of budding using the same two scions (Table VII). The scion buds were inserted in each case at nine inches above the soil level and lopping of the rootstock tops was carried out immediately after budding.

To study the nature of union between scion and rootstock, and its development in case of sweet orange and mandarin scions, each budded by both the methods (Indian and American), the material collected consisted of the scion portion with an inch or so of the rootstock portion on either side. The collection of material commenced on 8 March 1940 and was repeated thereafter at weekly intervals on three occasions; that is 15 March 1940, 22 March 1940 and 29 March 1940. Again, on 1 May 1940, when the bud sprouts were about two months old, the material was collected finally for the fifth time. On each of the five occasions, two samples representing each of the four treatments (sweet orange budded by the Indian method, sweet orange budded by the American method, mandarin budded by the Indian method, mandarin budded by the American method) were collected. Thus, in all, twenty different samples were collected, and on each occasion the material was preserved in formalin alcohol (95 c.c. alcohol *plus* 5 c.c. formalin).

Three months after preserving the material, the cutting of sections was tried with a wood-microtome in the Punjab University Botany Laboratories, Lahore, but due to the heaviness of the razor, brittleness of the material, and the violent force with which the razor struck the material, the scion separated from the stock—thus defeating the object of study. The material was again allowed to remain in the preservative for three months more and again the same machine was tried without any success.

It then occurred that the material should be fixed in Celloidion but unfortunately it was not available in India and could not be had from foreign countries due to War.

Thinking that hydrofluoric acid may soften the material, one specimen was put in HF (50 c.c. HF+50 c.c. H_2O) and was allowed to remain in it for three weeks. After this, the material was thoroughly washed in water and passed through different grades of water and alcohol to absolute alcohol and through grades of alcohol and xylol to pure xylol. The material was kept for four hours in each grade. The paraffin of the melting point of 58°C. was added to xylol and the material was kept on electric bath for three weeks. The temperature of the bath was kept constant at 62°C. Occasionally small bits of paraffin were added to the xylol containing the material until the whole xylol evaporated, leaving the material embedded in pure paraffin wax. Block was prepared and section cutting was tried on microtome but this method also did not prove successful.

After this, hand microtome was tried for cutting the sections. The microtome was fixed to the table with the material and free hand sections were cut with a razor. Though it was not possible to obtain complete sections, the union between scion and stock could be studied in the partially cut sections. Some good sections were selected from each specimen and were stained in Diamond Fuchsion and Light Green. The sections were put in a dilute solution of Diamond Fuchsion for two minutes, washed in water and, after passing through rectified spirit and absolute alcohol, were put in Light Green stain in alcohol. After the red stain was replaced by the green in soft tissues, the sections were washed in alcohol and put in clove-oil for clearing and differentiation of the tissues. Sections were washed in xylol to remove clove-oil and mounted in Canada Balsam. After this the slides were dried and ringed to form permanent preparations.

Layout

The method of lay-out, adopted in these experiments, conforms to the latest field plot technique, developed and advocated by Fisher [1935] for carrying out experiments with orchard crops. The two methods of budding and the three lopping treatments were tried in six possible combinations as follows :—

B_1P_1, B_1P_2, B_1P_3, B_2P_1, B_2P_2 and B_2P_3

The rootstock seedlings were labelled to indicate the category, based on diamter measurements, and each of the six above noted treatments was tried for each rootstock category in a randomized layout. The information about the treatment given to individual seedling. was also noted on the label tied to each selected seedling. The information about the diameter and the number of seedlings in different categories, selected for various experiments, along with the coefficients of variability determined in each case, is summarized in Tables II-VII.

TABLE II

Details of the experiments on the propagation trials with mandarin (Spring 1940)

Category	Diameter of seedlings (cm.)	C.V.	No. of seedlings used for various treatments						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·64	1·82	14	14	14	14	14	14	84
2	0·65—0·69	2·13	14	14	14	14	14	14	84
3	0·70—0·74	1·65	14	14	14	14	14	14	84
4	0·75—0·79	1·60	14	14	14	14	14	14	84
5	0·80—0·88	3·70	14	14	14	14	14	14	84
6	0·89—0·94	1·87	14	14	14	14	14	14	84
		Total .	84	84	84	84	84	84	504

TABLE III

Details of the experiments on the propagation trials with sweet orange (Spring 1940)

Category	Diameter of seedlings (cm.)	C.V.	No. of seedlings used for various treatments						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·69	4·40	14	14	14	14	14	14	84
2	0·70—0·74	1·65	14	14	14	14	14	14	84
3	0·75—0·79	1·52	14	14	14	14	14	14	84
4	0·80—0·84	1·24	14	14	14	14	14	14	84
5	0·85—0·89	1·40	14	14	14	14	14	14	84
6	0·90—0·99	3·01	14	14	14	14	14	14	84
		Total .	84	84	84	84	84	84	504

Table IV

Details of the experiments on the propagation trials with mandarin repeated in Summer 1940

Category	Diameter of seedlings (cm.)	C.V.	*No. of seedlings used for various treatments*						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·88	8·9	8	8	8	8	8	8	48
2	0·89—0·99	5·73	8	8	8	8	8	8	48
3	1·10—1·20	6·46	8	8	8	8	8	8	48
4	1·21—1·39	5·23	8	8	8	8	8	8	48
5	1·40—1·58	3·70	8	8	8	8	8	8	48
		Total	40	40	40	40	40	40	240

Table V

Details of the experiments on the propagation trials with sweet orange repeated in summer 1940

Category	Diameter of seedlings (cm.)	C.V.	*No. of seedling used for various treatments*						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·70—0·74	1·8	8	8	8	8	8	8	48
2	0·75—0·79	1·8	8	8	8	8	8	8	48
3	0·80—0·84	1·5	8	8	8	8	8	8	48
4	1·00—1·10	3·9	8	8	8	8	8	8	48
5	1·11—1·20	2·5	8	8	8	8	8	8	48
6	1·21—1·30	2·1	8	8	8	8	8	8	48
		Total	48	48	48	48	48	48	288

Table VI

Details of the experiments on the propagation trials with sour lime (Summer 1940)

Category	Diameter of seedlings (cm.)	C.V.	No. of seedlings used for various treatments			Total
			B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·64		31	31	31	93
2	0·65—0·69		31	31	31	93
3	0·70—0·74		31	31	31	93
4	0·75—0·79		31	31	31	93
5	0·80—0·83		31	31	31	93
6	0·85—0·94		31	31	31	93
		Total	186	186	186	558

Table VII

Details of the experiments on the anatomy and histology of union between two scions and a rootstock

Treatment	No. of seedlings budded		Total
	Sweet orange scion	Mandarin scion	
Indian method	21	21	42
American method	21	21	42
Total	42	42	84

The figures for coefficient of variability are very low, showing a close uniformity in the individuals comprising different categories in each experiment. Again, the variability between the categories themselves is also low, which means that these categories are directly comparable with one another.

Selection and preparation of bud-wood

Round, healthy and plump shoots of one season's growth were selected for propagation trials with sweet orange and mandarin bud-wood from a single tree was used in both cases and in both the seasons of budding. Scion-wood, used for sour lime (variety oval-shaped) propagation studies, was selected from several trees as sufficient wood on any single tree was not available. As much of it was cut daily as required. While removing leaves from bud-sticks, a portion of the leaf-stalk was left intact, which helped to protect the scion-bud and also helped in its handling. The bud-sticks were taken to the field after wrapping in wet hemp bag and the buds were removed by means of the sharp knife taking care that the knife always worked in the acropetal direction. Each bud, when removed, was about one inch long and had a little piece of wood attached to it on its under surface. The buds, as removed, were put in a cup containing water. The wood was removed from about half the number of buds, taking care that the germ or meristematic tissue of the buds was not injured.

Budding operation

The work of budding, which commenced on 22 February 1940, was performed exclusively by one budder. There was, therefore, no chance of variability being introduced due to human factor. For sweet orange budding, the bud-wood was collected from a tree of the Valencia Late variety. The scion used in the other plot was that of Nagpur mandarin variety. This was also collected from a single tree growing in the same orchard.

Budding started on 22 February 1940 in case of the sweet orange scion. Before budding, the leaves of the rootstock seedlings were removed up to about one foot from the ground level. Then, at a height of about nine inches from the ground level, on the northern side of the seedlings, two incisions (one horizontal and other longitudinal) approximately at right angle to each other were made with a budding knife. The bark flaps, at the junction of the two cuts, were raised slightly with the blunt edge of the knife for inserting the buds therein. Buds were inserted at this height to safeguard against gum disease infection, which usually comes from the soil. If, on the other hand, buds are inserted too high, a crooked and ugly trunk may result. The scion-buds were picked up one by one from the cup and inserted immediately from the upper side of the (T) and pushed in the downward direction for fitting into the cut. This operation was done very carefully to avoid injury to the tissues of the bud. After this, the buds were tied in position with raffia. This operation was started from the upper end of the inserted bud and finished at the lower end with a knot. The idea in inserting the scion buds on the north side was to protect them from the direct rays of the sun.

Removing the raffia

About 20 days after finishing the budding, the raffia was cut off by giving a longitudinal cut on the side opposite to the inserted bud. During this period, the scion buds were taken to have united with the stock even if no growth was visible.

Removing the stock sprouts

While examining the scion-bud sprouts, it was noticed that some buds on the rootstock portion had also sprouted. These sprouts were rubbed off without injuring the sprouts from the scion-buds.

Training the budded plants

In order to ensure a perfectly straight stem, the young sprouts were trained with stakes. When the sprouts had grown to a length of about three inches, they were tied to the stumps of rootstocks, usually left above the inserted buds. At the same time, stakes of *Saccharum sp.* (Sarkanda) were

provided to the budded plants and were fixed on the southern side, which was in a direction opposite to that on which scion-buds were inserted. The young sprouts were trained carefully along these stakes by tying with raffia at suitable intervals. The side branches on the main shoot were not allowed to grow and, after the main shoot had grown sufficiently tall, the rootstock stumps, left at two inches above the inserted buds, were cut close to the scion shoots. After the scion shoots had grown to a length of nearly a foot and a half, the side branches were also allowed to be formed. The budlings, thus trained, became ready for transplanting after about a year.

Data collected

It has been previously stated that a good deal of numerical data were collected in connection with the selection of material for carrying out the various investigations. The data connected with the problems under study, however, were collected after the seedlings had been budded. It comprised (*a*) the number of days required for bud-break in each case, (*b*) the percentage of bud-take in each case, (*c*) the vigour of the budlings under each treatment, and (*d*) the nature and development of union between stock and scion. In collecting data on all the four aspects mentioned above, the following procedure was adopted.

Time required for bud-break in each case

In spring 1940, the budding operations in case of the sweet orange and mandarin plots were finished on 25 February 1940 and 29 February 1940, respectively. The examination of the budded seedlings in both the plots was started on 3 March 1940 in case of sweet orange budding trials and on 7 March 1940 in case of mandarin budding. Observations were made daily and the sprouting of buds was recorded in the field register by using positive and negative signs. Thus +ive sign against a seedling on a certain date would show that bud-break started on that date, whereas the —ive sign would indicate that bud-break had not commenced. In cases, where growth died out after once starting, it was necessary to add negative sign with positive previously given. Similarly, for budding trials carried out and repeated in summer 1940 in case of sweet orange, mandarin and sour lime, the bud sprout records were also taken in the same way as in spring of the same year.

Percentage of bud-take in each scion variety

In calculating the percentage of bud-take in each case, the surviving budlings only were taken into consideration and those drying out after some time due to various causes were not included. The counts for bud-take were thus made after about three months of the time of budding in each case and in both the seasons.

Vigour of budlings under each treatment

About one year after the date of budding, the budded plants were measured for diameter by Vernier callipers at points approximately two inches above the union. The total extensional growth in cm. was also recorded for each budded plant by means of the meter-rod.

Nature and development of union between scion and stock

The procedure for preserving the material, section cutting and preparation of permanent slides has been described under the section on 'Methods employed'. Microphotographs of all the permanent slides were taken with a view to study the nature and development of the union between scion and stock for all the scion species budded by the two different methods.

Presentation of results

It has been previously mentioned that the data were collected from several view-points. The mass of figures, thus accumulated, were suitably compiled for statistical calculation and interpretation of results. Such mean tables concerning the various phases of study have been excluded in the interest of brevity. After working out the statistical constants in each case, summary tables were prepared which are presented and discussed here. The various phases of study embracing the present investigations have been presented below.

Period of bud-break as affected by various propagation methods and categories of root-stocks

The results under this item of study were available for both spring and summer seasons of budding in case of sweet orange and mandarin and for summer season alone in case of sour lime scion. The results for three scion varieties are presented separately as follows :—

(*a*) *Sweet orange budding trial carried out in spring 1940 and repeated in summer 1940.* A statistical study of the mean number of days required for sprouting of sweet orange buds that were inserted in the seedlings of various categories with respect to the two methods of budding and three after-treatments is presented as follows :

TABLE VIII

Period of bud-break in case of sweet orange scion as affected by various propagation methods and categories

(a) *Methods of budding*

Method of budding	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
B_1	15·16	0·47	19·58	3·05
B_2	14·41		19·26	

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
P_1	14·12	0·56	12·99	3·7
P_2	15·28		23·20	
P_3	14·95		22·06	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
1	14·5	0·82	19·32	5·30
2	15·9		19·66	
3	14·1		20·14	
4	14·6		17·79	
5	15·0		18·36	
6	14·6		21·24	

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TABLE VIII—contd

(d) Inter-action of method with after-treatment

	Spring 1940 Mean No. of days taken.			Summer 1940 Mean No. of days taken		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	14·46	16·14	14·87	12·03	24·42	22·27
B_2	13·78	14·43	15·03	13·96	21·98	21·85
Difference . .	00·68 (+)	1·71 (+)	00·16 (—)	1·13 (—)	2·44 (+)	00·42 (+)
C.D.		0·82			5·30	

The following conclusions can be made from the data presented in Table VIII.

(i) In spring 1940 the mean number of days taken for bud-break by the Indian method is 15·16 as against 14·41 by the American method. This shows that the American method of budding hastened the period of bud-break by 0·75 days on the average. This difference is apparently small but the effect of both methods of budding is so consistent for all the categories that even this small difference is significant. In summer 1940 both the methods behaved alike in influencing the period of bud-break.

(ii) The mean No. of days taken for bud-break is the least under P_1 as compared with other after-treatments for both the seasons. The differences in both cases are significant showing thereby that P_1 after-treatment should be preferred to the other two in reducing the period of bud-break.

(iii) Of all the categories tried, none has increased the period of bud-break except category No. 2 in spring season of budding. It can be infered therefore that, in general, the categories have not shown any effect on the period of bud-break.

(iv) The figures in the inter-action table show that in decreasing the period of bud-break B_2 is superior to B_1 only when the after-treatment followed in both cases is P_2. In case of P_1 also, the American method has given better results over the Indian method but the difference is not large statistically. The period of bud-break is the least for the combination B_2P_1, which shows that for both methods of budding, preference should be given to P_1 with a view to decrease the period of bud-break.

(b) *Mandarin budding trial carried out in spring 1940 and repeated in summer 1940.* A statistical study of the mean number of days required for sprouting of mandarin buds that were inserted in the seedlings of various categories with respect to two methods of budding and three after-treatments is presented below.

TABLE IX

Period of bud-break in case of mandarin scion as affected by various propagation methods and categories

(a) *Method of budding*

Method of budding	Spring 1940 Mean No. of days taken	Spring 1940 C.D.	Summer 1940 Mean No. of days taken	Summer 1940 C.D.
B_1	18·59	1·9	23·19	5·7
B_2	15·92		19·87	

TABLE IX—contd

Period of bud-break in case of mandarin scion as affected by various propagation methods and categories

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
P_1	16·42	2·38	13·91	8·07
P_2	17·78		22·34	
P_3	17·57		17·58	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
1	16·65	3·34	22·36	10·37
2	17·33		20·51	
3	18·52		20·85	
4	16·45		27·38	
5	17·18		16·65	
6	17·41		*Nil.*	

(d) *Inter-action of method with after-treatment*

	Spring 1940			Summer 1940		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	17·57	18·48	19·74	16·27	35·31	17·99
B_2	15·27	17·09	15·39	17·11	18·30	24·20
Difference	2·30 (+)	1·39 (+)	4·35 (+)	06·84 (—)	17·01 (+)	6·21 (—)
C.D.		3·34			11·29	

The following conclusions can be drawn from the data presented in Table IX.

(i) In spring 1940, the mean number of days taken for bud-break by the Indian method of budding is 18·59 as against 15·92 by the American method. And in summer 1940, the days required by the Indian method are 23·19 as against 19·87 required by the American method. It is clear, therefore, that American method of budding hastened the period of bud-break of mandarin by 2·67 days in spring and 3·32 days in summer. The difference is significant statistically in case of spring budding and is suggestive only in case of summer budding.

(ii) The mean number of days taken for bud-break is the least under P_1 and greatest under P_2 for both seasons of budding. In spring budding the differences are not significant but for summer budding P_1 has shown distinct superiority over P_2. In general, P_1 should be given preference to the other two after-treatments in case of mandarin budding also.

(iii) Of the various categories under trial none influenced the period of bud-break in case of spring budding. But in summer 1940, the seedlings of fifth category decreased the period of bud-break and, on the contrary, fourth category alone increased this period. All the remaining three categories have not, however, shown any effect on the period of bud-break.

(iv) The figures in the inter-action table show that the period of bud-break is the least under P_1 for both methods of budding and during both seasons of budding. However, the superiority of B_2 over B_1 lies in following the P_3 after-treatment in spring season of budding and P_2 after-treatment in summer season of budding.

(c) *Sour lime budding trial carried out in summer 1940.* A statistical study of the mean number of days required for sprouting of sour lime buds inserted in seedlings of various categories with respect to one method of budding and three after treatments is presented below.

TABLE X

Period of bud-break in case of sour lime scion as affected by the three after-treatments and categories of rootstock

(a) *After-treatments*

After-treatment	Mean number of days taken	Critical difference
P_1	23·50	
P_2	39·05	7·87
P_3	34·06	

(b) *Effect of categories*

Category	Mean number of days taken	Critical difference
1	29·40	
2	31·60	
3	31·92	
4	31·67	10·9
5	34·00	
6	34·70	

The following conclusions can be made from the data presented in Table X.

(i) The data in part (*a*) show that P_1 is significantly better than the remaining two after-treatments in reducing the period of bud-break in case of sour lime scion. The differences are significant even at one per cent level.

(ii) The data in part (*b*) show that root-stocks of different vigour have no influence on the period of bud-break.

Percentage of bud-take as affected by various propagation methods and categories of rootstocks

The results under this item of work were available for both spring and summer seasons of budding in case of sweet-orange and mandarin scions and summer season alone in case of sour lime scion. These results for the three scion varieties are presented separately as follows.

(*a*) *Sweet orange budding trial carried out in spring 1940 and repeated in summer 1940*. A statistical study of the percentage of take of sweet orange buds inserted in stock seedlings of various categories with respect to two methods of budding and three after-treatments is presented as follows.

TABLE XI

Percentage of bud-take in case of sweet orange scion as affected by three after-treatments and six categories of root-stock

(a) *Methods of budding*

Method of budding	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
B_1	92·1	6·72	80·6	11·8
B_2	93·2		83·3	

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
P_1	93·4	8·28	79·2	14·2
P_2	89·9		84·4	
P_3	94·7		82·3	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
1	91·7	11·56	81·3	20·27
2	95·2		81·3	
3	88·1		87·5	
4	93·0		77·1	
5	93·9		87·5	
6	94·1		77·1	

The following conclusions can be made from the data presented in Table XI.

(i) In case of sweet orange scion, the percentage of bud-take is not influenced by the methods of budding tried in case of both the seasons.

(ii) The three after-treatments, tried in both the seasons, have not influenced the percentage of bud-take.

(iii) There is no evidence of the influene of root-stock vigour on the percentage of bud-take during both the seasons of budding.

(*b*) *Mandarin budding trial carried out in spring 1940 and repeated in summer 1940*. A statistical study of the percentage take of mandarin buds inserted in stock seedlings of various categories with respect to two methods of budding and three after-treatments is presented below.

Table XII

Percentage of bud-take in case of mandarin scion as affected by two methods of budding, three after-treatments and six categories of root-stock

(a) *Method of budding*

Method of budding	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
B_1	83·3	10·02	51·7	
B_2	74·1		42·3	16·93

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
P_1	73·6		53·1	
P_2	78·73	11·54	28·1	20·52
P_3	83·75		36·5	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
1	85·7		50·0	26·72
2	85·7		47·9	
3	76·2	17·60	47·9	
4	74·4		45·8	
5	76·4		43·7	
6	73·8		Nil	

(d) *Inter-action of methods with after-treatments*

	Spring 1940			Summer 1940		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	85·8	74·4	86·5	80·0	37·5	37·5
B_2	61·4	80·0	80·9	47·5	30·0	50·0
Difference	24·4	5·6	5·6	32·5	7·5	12·5
	(+)	(—)	(+)	(+)	(+)	(—)
C.D.		17·60			29·00	

The following conclusions can be made from the data presented in Table XII.

(i) The data in part (a) show that the percentage of bud-take in case of mandarin scion can be considerably increased by following the Indian method of budding. The results for both the seasons are in favour of B., and the differences are high enough as compared with the critical limit.

(ii) The influence of after-treatments on the percentage of bud-take is interesting. In spring season, both P_2 and P_3 should be preferred to P_1, but on the contrary, P_1 should be given preference to others in summer season as it has given far better results in this season.

(iii) The various categories of root-stock do not materially differ from one another in affecting the percentage of bud-take. But it is evident that the thicker the stock seedling, the least the percentage of bud-take.

(iv) The figures in the inter-action table show that the Indian method of budding significantly established superiority over the American method of budding when P_1 after-treatment is followed in both cases. This is true for both the seasons of budding.

(*c*) *Sour lime buddng trial carried out in summer, 1940.* A statistical study of the percentage take of sour lime buds inserted in stock seedlings of various categories with respect to three after-treatments is presented below.

TABLE XIII

Percentage of bud-take in case of sour lime scion as affected by three after-treatments and six categories of root-stock

(a) *After-treatments (Summer 1940)*

After-treatment	Mean percentage of bud-take	C.D.
P_1	55·66	15·02
P_2	23·2	
P_3	35·2	

(b) *Effect of categories (Summer 1940)*

Category	Mean percentage of bud-take	C.D.
1	34·3	21·39
2	40·1	
3	28·0	
4	39·4	
5	42·4	
6	43·4	

The following conclusions can be drawn from Table XIII.

(i) P_1 after-treatment resulted in the highest percentage of bud-take as compared with the other two. The differences are statistically significant in each case.

(ii) Of the various categories under trial, all but No. 3 behaved alike in influencing the percentage of bud-take. The influence of No. 3 also is not significant statistically from the remaining categories.

The vigour of one-year old budded trees as affected by various propagational methods and categories of root-stock

The results under this item of work are available only for spring budding trial carried out in case of sweet orange and mandarin. The measurements of budlings were recorded a year after the

time of budding. The results for two scion varieties are presented separately both for diametrical girth and total growth as follows.

Diametrical girth and total growth of sweet orange budlings. A statistical study of the mean diametrical girth and mean total growth of the sweet orange budlings on stock seedlings of various categories with respect to the two methods of budding and three after-treatments is presented below.

TABLE XIV

Diametrical girth and total growth of sweet orange budlings as affected by various propagation methods and categories

(a) *Methods of budding*

Method of budding	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
B_1	0·840	0·05	229·5	19·16
B_2	0·792		203·7	

(b) *After-treatments*

After-treatment	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
P_1	0·86	0·04	224·1	23·61
P_2	0·82		221·4	
P_3	0·78		204·3	

(c) *Effect of categories*

Category	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
1	0·72	0·088	133·8	33·4
2	0·79		201·9	
3	0·77		205·9	
4	0·83		222·0	
5	0·83		226·2	
6	0·85		259·8	

TABLE XIV—*contd.*

Diametrical girth and total growth of sweet orange budlings as affected by various propagation methods and categories

(d) *Inter-action of method with after-treatment*

	Diametrical girth in cm.			Total growth in cm.		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	0·897	0·872	0·752	237·3	255·3	195·8
B_2	0·813	0·770	0·810	210·9	187·5	212·7
Difference . . .	0·084 (+)	0·102 (+)	0·058 (—)	26·4 (+)	67·8 (+)	16·9 (—)
C.D.	0·088			33·4		

The following conclusions can be made from the data presented in Table XIV :—

(i) The Indian method of budding shows statistically significant superiority over the American method of budding in producing vigorous and well developed sweet orange plants.

(ii) P_1 after-treatment helped to produce vigorous and well developed plants as compared with P_2 and P_3. As regards diametrical girth the differences are statistically significant, but for total extentional growth the differences are not quite significant.

(iii) The thicker the stock-seedling the more vigorous are the plants produced on it.

(iv) The figures in the inter-action table show that in case of the Indian method of budding, P_1 and P_2 gave nearly indentical results but in case of American method, P_1 and P_3 should be preferred to produce better sized trees in the same period.

Diametrical girth and total growth of mandarin budlings. A statistical study of the mean diametrical girth and the mean total growth of the mandarin budlings, propagated on stock seedlings of various categories with respect to two methods of budding and three after-treatments is presented below.

TABLE XV

Development of mandarin budlings as affected by various propagation methods and categories

(a) *Methods of budding*

Method of budding	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
B_1	0·697	0·013	349·5	65·57
B_2	0·689		331·5	

(b) *Effect of after-treatments*

After treatment	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
P_1	0·83		456·4	
P_2	0·62	0·0155	251·8	80·34
P_3	0·62		333·5	

TABLE XV—*contd.*

Development of mandarin budlings as affected by various propagation methods and categories

(c) *Different categories*

Category	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
1	0·64	0·022	306·9	113·74
2	0·69		327·1	
3	0·73		388·7	
4	0·61		262·8	
5	0·73		368·3	
6	0·74		389·4	

(d) *Effect of inter-action of method of budding with after-treatments*

	Diametrical girth in cm.			Total growth in cm.		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	0·88	0·64	0·55	511·7	263·6	273·5
B_2	0·78	0·60	0·68	401·1	239·9	353·6
Difference	0·10 (+)	0·04 (+)	0·13 (—)	110·6 (+)	23·7 (+)	80·3 (—)
C.D.	0·022			113·74		

The following conclusions can be made from Table XV :—

(i) The Indian method of budding resulted in producing comparatively more vigorous trees of mandarin in the same period as compared with the American method. The differences, however, are not large enough to be significant statistically.

(ii) P_1 treatment proved significantly better than both P_2 and P_3 for producing better sized trees.

(iii) The thicker the stock seedling, the better the size of budlings produced on it. This observation was offset only by seedlings in category No. 4.

(iv) The data in the inter-action table show marked superiority of P_1 in case of both the methods of budding tried. Thus larger sized plants can be produced by either method of budding if the seedling top is cut off immediately after budding.

Nature and development of union between scion and root-stock

The material for this study was collected for the first month at weekly intervals after budding and thereafter once again when the inserted buds were two months old. The procedure for preserving the material, the cutting of sections and preparation of the permanent slides has been laid down already under the section on 'Methods employed'. The microphotographs of all the slides were taken to make a detailed study of the nature and development of union between scion and root-stock. The results for the two scions, namely sweet orange and mandarin have been presented separately as under.

Union of sweet orange buds with rough lemon root-stock. In Plate I, figs. 1, 2 is shown the course of development of union after a week from budding of sweet orange buds inserted respectively by the

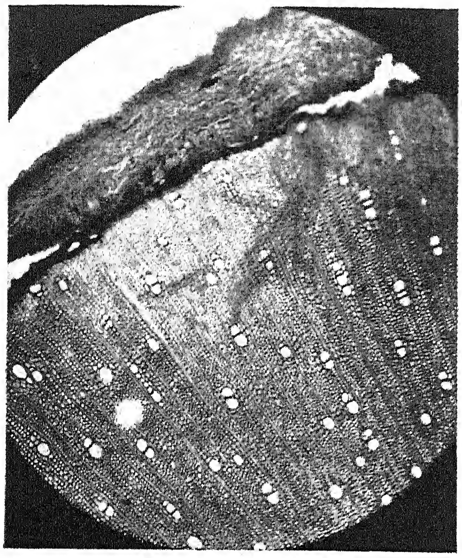

FIG. 1. Indian method

FIG. 2. American method

One week old union of sweet orange buds with rough lemon rootstock, budded by different methods of budding

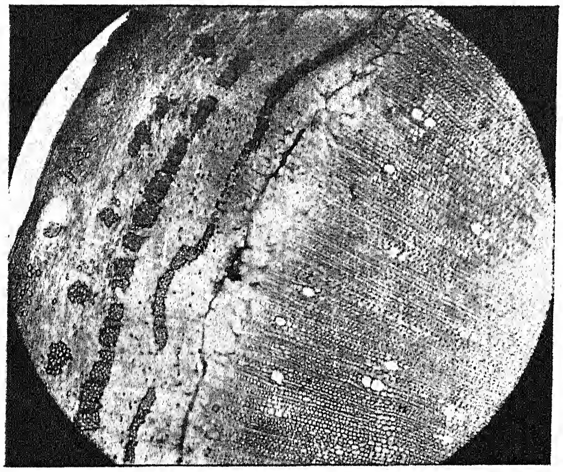

FIG. 3. Indian method

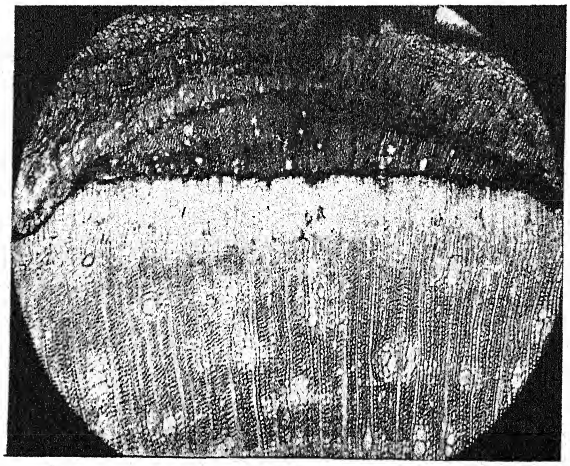

FIG. 4. American method

Two months old union of sweet orange buds with rough lemon rootstock budded by different methods of budding

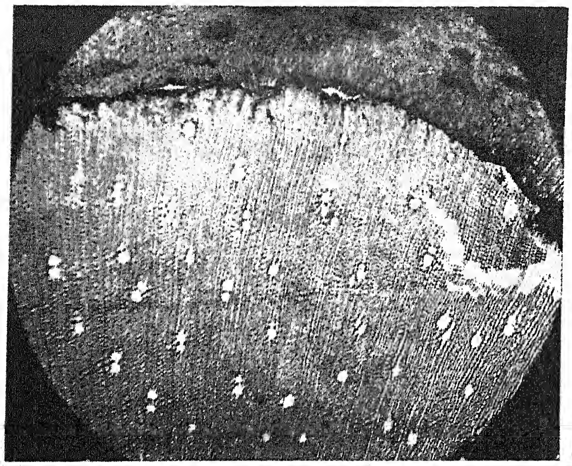

FIG. 1. Indian method

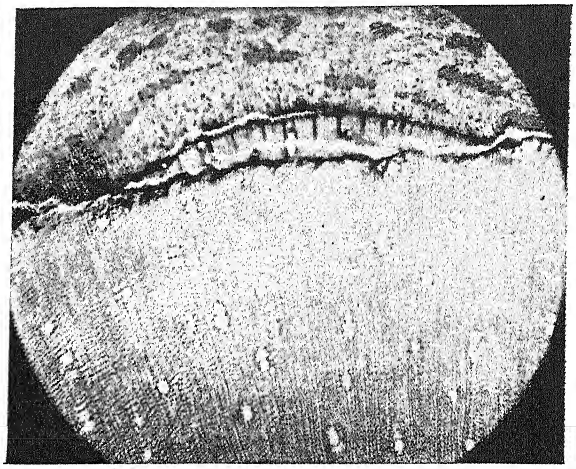

FIG. 2. American method

One week old union of mandarin buds with rough lemon rootstock budded by different methods of budding

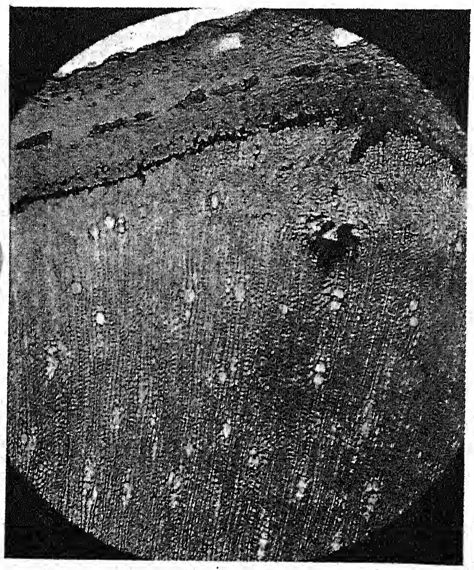

FIG. 3. Indian method

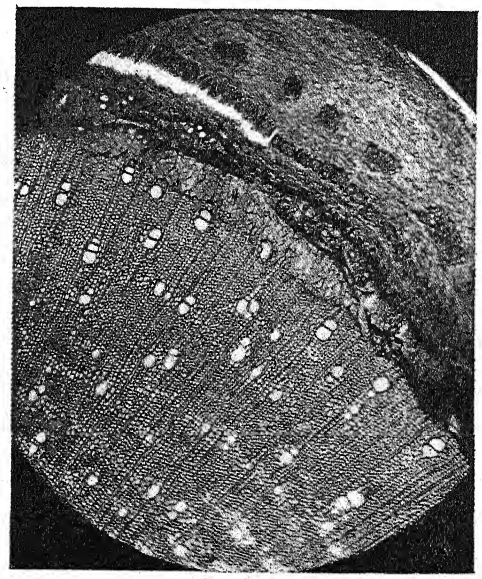

FIG. 4. American method

Two months old union of mandarin buds with rough lemon rootstock budded by different methods of budding

Indian and American methods of budding. There is slight formation of callus tissue joining the stock and scion only in the middle by the Indian method (Plate I, fig. 1) but there is no indication of such union taking place near the upper and lower ends. On the other hand, by the American method (Plate I, fig. 2) there is no indication of callus formation either in the middle or near the ends of uniting surfaces except that there is slight callus formation near such portions of the scion buds as are free from the woody tissue.

The callus formation took place two weeks after budding by Indian method at various points to provide union between scion and stock, leaving only a few gaps where callus tissue has not developed properly. On the other hand, by the American method the callus formation took place only near the ends, probably for the reason that these were free from the woody tissue. In other words, the woody tissue has served to inhibit the formation of callus thereby delaying the proper union between scion and root-stock.

Three weeks after budding, the formation of callus by the Indian method took place over the entire surface and the initiation of small celled tissue occurred both from the scion and the root-stock. On the other hand, by the American method the formation of callus is interrupted at several points and the small celled tissue developed only from one side, viz. the root-stock. In case of four weeks old material prepared by Indian method is noticed the complete union between scion and root-stock. The tendency to form vascular bundles on the scion bud is also noticed. The small celled tissue from both the uniting sides has inter-mingled at various points by breaking the callus. On the other hand, in case of material of the same age prepared by American method the union between the scion and root-stock is not complete, but that it took place at several points. The small celled tissue has also developed at several points but no intermingling of the same has resulted.

In case of the two months old material prepared by the Indian method, (Plate I, fig. 3) is seen the complete intermingling of tissue. The differentiation of vascular tissue has also completed in the scion portion. Thus the union between scion and root-stock may be said to have completed after two months. In case of material of the same age, prepared by the American method (Plate I, fig. 4) there is an alround retardation in various processes leading to the complete formation of union. Thus the intermingling of tissue has not taken place at several points. The formation of vascular bundles had started but it has, by no means, completed as yet.

Union of mandarin buds with rough lemon root-stock. In Plate II, figs. 1 and 2 is shown the course of development of the union of mandarin buds with rough lemon root-stock after a week from budding. The material shown in Plate II, fig. 1 was budded by the Indian method and that shown in Plate II, fig. 2 was budded by the American method. In Plate II, fig. 1, the formation of callus is seen at many points excepting two or three gaps, whereas in Plate II, fig. 2, the tendency for callus formation does not exist at any point except at one extremity.

In case of two weeks old material prepared by the Indian method, the callus tissue between the scion and root-stock has been formed completely. There is also a tendency towards the formation of small celled tissue. In case of material of the same age prepared by the American method on the other hand, the formation of callus has taken place only at such points as are free from the woody tissue. However, a tendency for the formation of vascular bundle in the scion is imminent.

In case of four weeks' old material prepared by the Indian method, intermingling of the tissue has taken place and formation of vascular tissue in the scion has also commenced.

On the other hand, in case of material of the same age prepared by the American method, even the small celled tissue has not developed completely on the side of scion probably due to the presence of the strip of wood. The formation of vascular bundles in the scion in this case, however, is far advanced as compared with the Indian method.

Two months after budding, the union by the Indian method (Plate II, fig. 3) appeared to be comparatively better than by the American method (Plate II, fig. 4). By the Indian method, the union was complete in every respect after two months and the differentiation of vascular bundles in the scion had also taken place. By the American method on the other hand, the inter-mingling of the small celled tissue had not taken place completely in an equivalent period of two months but the vascular bundles in the scion were completely formed and were clearly visible.

Discussion

The Indian versus the American method of budding

So many important issues have been raised by this study that it is difficult to give them all an adequate discussion within the limits of the present paper. The observations made and the data reported in the foregoing pages lead to the conclusion that the Indian method of budding should be preferred to the American method, in case the scion buds are free of thorns. But in the event of the thorns being present in close proximity to the scion buds, the method to be used must necessarily be the American one, as any effort to remove the buds, clean of the wood, as is done in case of the Indian method, would fail because the meristamatic tissue of the buds would be punctured by the thorns thereby lowering the efficiency of take.

The above conclusion is based on the study of several factors involved in the successful technique of nursery tree propagation of sweet orange and mandarin, as for instance the period of bud-break, the percentage of bud-take, the nature and development of the scion bud union and the vigour of budlings. The results showed that whereas the presence of wood under the scion-bud might serve a useful purpose in stimulating early growth of inserted scion buds, this, on the other hand, had not influenced the bud-take. It may be noted that the American method of budding was quite unknown to the Indian nurserymen till only a decade back when it was first put into practice at Lyallpur for propagating such important citrus fruits as the newly introduced grape-fruit and the old Indian favourite the *Kaghzi nimboo* or sour lime.

Coming to the relatively more important issue, viz. the percentage of bud-take, it is clear that the two methods of budding should now be regarded as equally efficient as both did not materially differ from each other in influencing the 'take' of buds. This is in conformity with the results obtained previously in the Punjab (Lal Singh, 1936). The data further suggest that preference, if any, should be given to the Indian method of budding so far as the propagation of mandarin trees is concerned.

On comparing the nature and development of bud-union, as taking place between the scion and root-stock by these two methods of budding, it is at once clear that the union by the Indian method not only materialized in a shorter period but it was also more perfect as compared with that obtained by the American method. Even after two months of budding, the union by the American method remained incomplete due mainly to the presence of wood portion which did not allow the cambium tissues of stock and scion to come into close proximity and establish the union. These results corroborate those obtained by Mendel [1936] who in summing up the results of his investigations remarked 'For all practical purposes, the budding in citrus should be done without wood'.

In conclusion, therefore, it appears that under conditions where both methods of budding have equal chance of being adopted and where the discrimination in their use lies in individual preference only, the Indian method should be preferred as, in practice it would be possible to raise bigger sized nursery trees in the same period by this method as compared with the American method.

Influence of after-treatments

It has been conclusively proved that under conditions of the present investigations, P_1 (lopping immediately after budding) produced outstandingly the best results as compared with the other two treatments. It reduced the period of bud-break in case of all the three scions, it exhibited a marked influence on tree size for both the scions and it proved to be singularly the best treatment for significantly increasing the percentage of bud-take in case of *Kaghzi nimboo*, although in this particular respect its influence on the other two scions is not well marked. In general, therefore, the superiority of this treatment of lopping over the other two, has been clearly established. Naik [1939] recorded similar influence of this treatment on the period of bud-break but for some unexplained reasons the shoots starting early growth in his trials ultimately lagged behind in size and development.

It is obvious, therefore, that the kind of treatment imparted to the stock seedling top after inserting the scion-bud plays an important role in precisely determining the various indices of growth. This conclusion based as it is on the evidence presented in this paper is a point of considerable practical

and theoretical importance. On the one hand, it establishes the superiority of a particular treatment in nursery production technique and on the other it lends support to the hypothesis adumbrated by Loeb [Summers, 1924]. It is, therefore, clear that whatever the explanation in favour of P_1, the stimulation for the growth of a newly inserted scion-bud is no concern of the portion of root-stock above it. In fact, the delay caused in lopping the seedling top adversely affected this stimulus. It is often said that leaving the stock seedling intact along with leaves after bud-insertion is advantageous and essential for getting desirable results but the data here reported have proved beyond doubt that this view is highly fallacious.

Influence of the vigour of stock seedlings

Root-stock seedlings of six different categories selected with regard to vigour, were budded with each of the three scions namely sweet orange, mandarin and sour lime. The results showed that the vigour of root-stock had no influence on the period of bud-break and the percentage of bud-take. There was, however, an indication that increased vigour of root-stock seedling might adversely affect the 'take' in case of mandarin, but in case of the other two scions no adverse effect of this kind was experienced.

The influence of root-stock vigour on the development of scion-bud growth is most marked. Thus after a year from budding, the sweet orange and mandarin trees were bigger in size on the comparatively more vigorous stock seedlings used. In other words, when the thickness of root-stock, at nine inches above soil level, ranged between 0·6 and 1·6 cm., the thicker the stock seedling, the better sized the nursery tree. This response of bud-growth, however, had not been surprising in view of the fact that initial increased vigour of root-stock must eventually express itself in increased size of budling on account of its having a comparatively larger root-system.

It is, therefore, concluded that the vigour of root-stock, used in these trials, influenced neither the period of bud-break nor the percentage of take of buds. This, on the other hand, significantly increased the size of budlings—the increase in size being directly proportional to the vigour of stock seedlings used.

Influence of the seasons of budding

It now remains to discuss if the conditions obtaining in the two seasons of budding had any influence on the growth indices relating to nursery tree propagation. In this connection it should be noted that this information was available for bud-break and bud-take in case of two scions namely sweet orange and mandarin and results on the number of days taken for bud-break and the percentage of bud-take were in favour of spring budding for both the scions. This suggests that the activity of cell sap for propagation was better in spring than in the summer season.

It may be added that the growth of bud sprouts was arrested with the approach of winter which followed soon after the season for summer budding was over. Other disabilities usually connected with the summer season of budding are (a) showers of rain which considerably lower the take of buds and (b) the severe frost of winter which may kill young bud growths of summer budding.

It is, therefore, evident from the above that spring season should be preferred, as far as possible to the summer season for budding purpose.

Summary and conclusions

(1) A study of the propagation methods with three citrus species namely sweet orange, mandarin and sour lime was made in which two methods of budding and three after-treatments were compared in relation to six vigour categories of stock seedlings.

(2) The two methods of budding proved equally efficient so far as the take of buds in case of sweet orange was concerned. In case of mandarin budding trial, the results were appreciably in favour of the Indian method but the differences produced by the two methods were not statistically significant.

(3) Other things being equal, it was possible to obtain bigger sized nursery trees of sweet orange and mandarin by the Indian method as compared with the American method.

(4) The Indian method of budding resulted in early and complete development of union between scion and root-stock as compared with the American method.

(5) The practice of lopping the stock seedling top immediately after budding proved significantly superior, in all respects, to the other two practices in case of all the three scions under study.

(6) The increase in the size of budlings was directly proportional to the vigour of stock seedlings used. There was, however, no influence of stock vigour on the period of bud-break and percentage take of buds for all the three scions tried.

(7) The conditions obtaining in spring season proved more favourable to decreasing the period of bud-break and increasing the take of buds than those in the summer season.

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A NOTE ON THE PREDICTION OF SPINNING VALUE OF GAORANI (BANI) COTTONS

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It is well known that one of the most important factors in determining the quality of cotton is the spinning performance of its lint which is correctly estimated only by carrying out spinning tests under controlled conditions and expert supervision. Such tests, however, are both expensive and time-consuming. So far as a cotton breeder is concerned, it is a matter of utmost importance for him to know from fibre tests carried out on small samples, the probable spinning performance of his selections at as early a stage as possible, so that he may confine his attention to the desirable strains. This would save a large amount of labour, money and time that may be spent on such strains as may prove unsatisfactory from the spinning point of view at a later stage. Apart from the breeder, the consumer of cotton is also deeply interested in this problem, since he is anxious to purchase such cottons in the market as would suit his spinning requirements, but he has hardly the time to undertake actual spinning tests before making his final selections.

In view of these reasons, both cotton breeders and buyers are often constrained to base their judgement of spinning value on the fibre properties of the material presented to them. It is generally believed that the spinning performance of a cotton is closely related to the length, fineness and strength of its fibres, and, as such, both breeders and buyers employ their own methods for estimating these characteristics. It is largely on the basis of his estimate of these factors, derived from his practical experience, that a buyer purchases cotton of different types for the mills. Similarly, a breeder makes a quick determination of the values of these fibre properties and forms his judgement of the probable spinning value of his material. These rough and ready methods are, however, attended with errors of personal judgement, and as such can only be regarded as approximately correct.

Previous work

On account of the importance of this problem to cotton breeders, traders and consumers, many research workers have tried in the past to evolve formulae for the prediction of the spinning value of cotton from its fibre properties. Nazir Ahmad [1941] reviewed the position in regard to Indian cottons and pointed out that although considerable progress had been made in the last 20 years, yet there was scope for improving the efficiency of the existing prediction formulae.

The first prediction formula for Indian cottons was given by Turner and Venkatraman [1934] as a result of their studies on the fibre properties of 95 samples of standard Indian cottons. It was as follows:

$$X_1 = 75{\cdot}4\, X_2 - 79{\cdot}5\, X_3 - 22{\cdot}8 \qquad (1)$$

where X_1 = Highest standard warp counts,
X_2 = Mean fibre length (inches)
X_3 = Fibre weight per inch (10^{-6} oz.)

It was pointed out by them that, when both fibre length and fibre weight per inch were taken into account, the prediction formula agreed with actual results within 10 per cent in 44 cases out of 100 and within 20 per cent in 76 cases out of 100.

Subsequent to the above investigations, the technique of determining fibre weight per inch underwent a change in the Technological Laboratory, Matunga, and, as such, it was deemed necessary to work out the above formulae on the basis of new records for fibre weight per inch. As a result of studies on 153 samples, Nazir Ahmad [1941] evolved the following formula for predicting the spinning performance of Indian cottons on the basis of the above mentioned two major fibre properties:

$$X_1 = 78{\cdot}9\, X_2 - 79{\cdot}2\, X_3 - 24{\cdot}8 \qquad (2)$$

The agreement of the predicted values on the basis of this formula and the actual values was within 10 per cent in 44 cases out of 100 and within 20 per cent in 74 cases out of 100.

Nazir Ahmad [1941] further stated that work in this connection was being continued by dividing the Indian cottons into four major groups, viz. (i) inferior strains, (ii) superior Indian strains, (iii) exotic strains, and (iv) strains peculiar to the Gujarat tract. Separate prediction formulae have been worked out for each group on the basis of their fibre properties which give a much better agreement with the actual tests.

It will be noticed that the above formulae have been obtained by grouping Indian cottons belonging to different species more on the basis of their physical properties than on their biological affinities. It was, therefore, felt worthwhile to find out whether grouping cottons on the basis of their botanical classification might not improve the efficiency of the prediction formula for certain classes of cottons.

Hutchinson and Ghose [1937] classified the genus *Gossypium* on the basis of the evolutionary trends, etc., and showed that the Bani (Gaorani) cottons of Hyderabad State were quite different from the north Indian arboreums belonging to the class *G. arboreum* var. *neglectum* forma *bengalensis*. Since the results of fibre and spinning tests, carried out on a large number of samples at the Technological Laboratory, Matunga, were available, an attempt has been made in this paper to study the regression of the fibre properties on the spinning value and to evolve the prediction formulae for cottons belonging to this class.

Prediction of spinning value of Gaorani cottons

During the period 1932-1941, 111 samples of Gaorani (Bani) cotton belonging to the group *G. arboreum* var. *neglectum* forma *indica* were tested for their fibre properties and spinning performance in the Technological Laboratory, Matunga. The available data has been utilized to evolve a prediction furmula for these cottons. Accordingly, correlation coefficients were calculated between (1) mean fibre length (inch), and (2) mean fibre weight per inch (10^{-6} oz.) on the one hand and the actual values of standard warp counts on the other; the results obtained are given in Table I.

A study of the mean fibre length data of these 111 samples showed that a large number of them covered a small range of mean fibre length, and as such it was considered desirable to see if better results would be obtained by omitting the results of 18 samples. However, the new values thus obtained (Table I) did not differ significantly from those obtained by taking all the 111 samples. This feature indicates the homogeneous nature of the group.

TABLE I

Correlation coefficients between mean fibre length and mean fibre weight

Correlation coefficients between		For 111 Gaorani samples	For 93 Gaorani samples
H. S. W. C.			
Mean fibre length (inch)	r_{12}	+0·343	+0·361
	r_{13}	—0·653	—0·673
Mean fibre weight (10^{-6} oz.)	r_{23}	—0·026	—0·024
	$r_{13\cdot2}$	—0·686	—0·712
	$r_{1(23)}$	0·730	0·756

Table II gives the comparative values of the above correlation coefficients with those obtained by Turner and Venkatraman and Nazir Ahmad for the Indian cottons taken collectively, i.e., irrespective of the biological grouping.

TABLE II

Correlation coefficients between highest standard warp counts and fibre length and mean fibre-weight per inch

Between highest standard warp count	Turner and Venkatraman	Nazir Ahmad	Gaorani samples 111
	95 samples standard Indian cottons	153 samples standard Indian cottons	
Fibre length	+0·87	+0·89	+0·34
Fibre weight per inch	—0·80	—0·83	—0·65
Fibre weight and fibre length	+0·92	+0·91	+0·73

It will be seen from the above results that the correlation coefficients total, as well as multiple, are lower for the Gaorani cottons than for the whole set of standard Indian Cottons. Furthermore, while the correlation coefficients between the highest standard warp counts and mean fibre length and mean fibre weight per inch are nearly equal for the standard cottons, the fibre weight per inch appears to be more important in determining the spinning performance of Gaorani strains than the mean fibre length. This may be an inherent feature of these cottons or it may be due to the small spread of the values of mean fibre length for a large number of the Gaorani samples.

Prediction formula for Gaorani cottons based on the values obtained for 111 Gaorani samples has also been worked out and is found to be as follows:

$$X_1 = 65{\cdot}37\ X_2 - 251{\cdot}98\ X_3 + 19{\cdot}18 \quad \ldots \quad (3)$$

where X_1=H.S.W.C.

X_2=Mean fibre length (inch)

X^3=Mean fibre weight (10^{-6} oz.)

Comparing the actual values of H.S.W.C. obtained for these samples with those predicted on the basis of the above formula it has been found that the agreement within 10 per cent was in 47 cases out of 100 and within 20 per cent in 82 cases of 100. The efficiency of the above formula as compared with those published recently for the India cottons is shown in Table III.

TABLE III

Agreement between actual spinning values and those from formulae for 111 Gaorani strains

Formula	Percentage of samples for which actual H.S.W.C. does not differ from predicted by more than	
	10 per cent	20 per cent
$X_1=78{\cdot}9\ X_2-79{\cdot}2\ X_3-24{\cdot}8$ (Nazir Ahmad, 1941)	34	68
New formula (in course of publication)	42	72
$X_1=65{\cdot}37\ X_2-251{\cdot}98\ X_3+19{\cdot}18$ (proposed for Gaorani cottons)	47	82

It will be seen that as compared with the older formula the formula given above is likely to be of greater use for predicting the spinning performance of Gaorani (Bani) cottons on the basis of their mean fibre length and mean fibre weight (10^6—oz.)

ACKNOWLEDGEMENT

The work, both at Matunga and of Hyderabad Cotton Research (Botanical) Scheme, was carried out from the funds of Indian Central Cotton Committee.

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H

ABSORPTION POWER OF PLANT MATERIALS

By L. D. Mahajan, M.Sc., Ph.D., F.Inst.P., F.R.S.A., Professor of Physics, Mahendra College, Patiala

(Received for publication on 22 April 1946)

(With two text-figures)

SOME years ago, Ramdas and co-workers [1938, 1939] investigated the phenomenon of exchange of moisture between the air layers near the ground and substances like the soils, plant leaves, seeds, etc. exposed to the atmosphere. They dealt with the grains of wheat, paddy, *bajri*, *jowar*, etc. It was observed that the plant materials exchange moisture with the atmosphere sourrounding them. The moisture content in them was maximum at the minimum temperature epoch, and minimum at the maximum temperature epoch. But now the author has studied the absorption power of the plant materials, such as Patiala chillies, their seeds, cover, wood and leaves in their natural forms as well as their powders. The effects of their age, the percentage of humidity of the surrounding air, the time and the other physical conditions on their absorption power have also been studied. Their absorption power has been compared with those of the soils and other plant materials, and some interesting results have been found.

Classifications

Patiala, the capital of Patiala State, is one of the best centres of large production of chillies. The chillies of this part of the country have been divided according to their physical properties, into four classes, namely, PT1, PT2, PT3, and PT4.

(i) *PT1.* These chillies are long, thin, and yellow. Their length varies from about 7 cm. to 9 cm. and diameter from about 0·5 cm. to 1·0 cm.

(ii) *PT2.* They are long, thin, and red. Their length varies from about 7cm. to 9 cm. and diameter from 1·0 cm. to 1·5 cm.

(iii) *PT3.* They are not very long, but are thick and red. Their length varies from about 6 cm. to 7 cm., and diameter about 1·5 to 2·0 cm.

(iv) *PT4.* They are dwarf and red. Their length varies from about 3 cm. to 3·5 cm., and diameter from about 1·5 cm. to 2·0 cm.

The hill chillies of Patiala State were also examined. They are divided into two classes, i.e. the big and the small ones.

(i) *Big chillies.* Their diameter varies from 3 cm. to 8 cm. and length from 3 cm. to 10 cm. Their cover is comparatively much thicker. They are much less bitter than the others and are either green or red.

(ii) *Small chillies.* They are small in size. Their length varies from 3 cm. to 5 cm. and diameter from 0·5 cm. to 1·5 cm. Their cover is thin. They are very bitter and are generally red.

Apparatus

In order to study the hygroscopic properties and absorption power of the chillies, the air dried chillies in natural form were kept in glass chamber wherein the relative humidity could be altered, according to the requirements. For this purpose, the author [1940] used his old apparatus which he had devised for the study of absorption of moisture by soils from the moist air. In each case the period of exposure to the moist air was 24 hours.

Method

The power of absorption of the substances was calculated in percentage for maximum increase of humidity. The following formula was used:

$$\text{Power of absorption} = \frac{W \times 100}{W}$$

where w is the increase in weight of the substance for maximum change of humidity, and W is the initial weight of the substance at 0 per cent humidity.

Observations

By the use of this apparatus, the following observations (Table I) were recorded. Table I shows percentage of increase of weight of Patiala chillies by absorption of moisture from the moist air for maximum change of humidity of the surrounding air but other conditions remain the same.

Table I

Percentage of increase of weight of Patiala chillies by absorption of water from moist air

Material	Quality	Increase in percentage of humidity	Percentage of absorption power
Chillies PT1	Fresh	0 to 100	26·0
,, PT2	,,	,,	27·0
,, PT3	,,	,,	27·5
,, PT4	,,	,,	27·4
,, PT3	One year old	,,	7·0
,, PT4	,,	,,	5·0
Chillies wood	Fresh	,,	10·0
,, leaves	,,	,,	14·0
,, wood	Powder	,,	12.0
,, leaves	,,	,,	24·0
Hill chillies (big)	Fresh	,,	30·0
,, ,, (small)	,,	,,	29·0

In order to study whether absorption of moisture is mainly due to the cover of the chillies or their seeds, the experiments were performed with the same apparatus. The observations are given in Table II which gives the percentage of increase in weight of the seeds and the cover of the chillies by absorption of moisture from the surrounding air, when the relative humidity of the surrounding air increases from 0 to 100 per cent the other conditions remaining the same.

Table II

Percentage of increase in weight of seeds and cover of chillies by absorption of moisture from surrounding moist air

Material	Part	Increase in percentage of humidity	Percentage of absorption power
Patiala chillies	Cover	0 to 100	31·2
Hill chillies	,,	,,	35·0
Patiala chillies	Seeds	,,	19·6
Hill chillies	,,	,,	15·2

Discussion of results

Table I indicates that the chillies absorb moisture from the surrounding air when they are exposed to it. They behave like other plant materials, such as, wheat, *jawar*, paddy, etc., which exchange moisture with the atmosphere surrounding them. A comparison of the results obtained by Ramdas and co-workers [1938, 1939] with the observations given above in Table I shows that the chillies absorb much more moisture from the surrounding air than most of the other plant materials. The average maximum amount of moisture which the chillies can absorb is about 27 per cent. It is very high power when compared to other various kinds of plant materials, such as, grains of wheat, *jawar*, paddy, cereals, etc., and their leaves.

The comparison indicates that the chillies behave like soils. The dry plant-materials of the chillies exchange moisture with surrounding atmosphere like the soils, and have higher absorption power than that of the soils which have been already studied by the author [1940] in one of his previous papers. The absorption power of the wood is much less than that of the leaves, and the leaves have much less power than the chillies.

The powder of the chillies is very hygroscopic in character. Its hygroscopic power is higher than that of chillies in natural form. The hygroscopic power of the powder of the wood of the chillies is 2 per cent more than that of its wood. Similarly the hygroscopic power of the powder of the leaves is almost double than that of its leaves in natural form. Thus the powders of the plant materials are much more hygroscopic than the corresponding plant materials in natural form. The material produced by crushing of the fresh young plants has been found to be a better absorber of moisture than that of the old and well grown up plants. The powder of the seasoned wood has very little absorption power.

This seems an important result for it shows that the finely powdered dry plant materials produced by crushing of the young plants, preferably the leaves, increases the power of absorption of the soils when mixed with soils. It reduces the frequency of watering the soil, and thus may reduce the cost of irrigating the land. It may also help in dry farming. The powder of the cow dung cakes serves the same purpose as well. This result has already been discussed by the author [1942] in one of his previous papers.

Table I indicates that the maximum amount of moisture absorbed by the chillies varied slightly, i.e. from 25 per cent to 28 per cent. The chillies PT3 and PT4, which are thick, absorb more moisture than the others. Thus the thick covering absorbs more moisture than the thin ones.

The same table further shows that the chillies after about one year have very much less absorption power than when they were fresh. Thus the age of the chillies affects their absorption power. The older they are, the less is their absorption power.

Table II represents that the cover of the chillies has about twice the power of absorption of their seeds. The cover which is very delicate and soft, absorbs more moisture than their seeds which are hard in texture and heavy in weight. Thus the cover of the chillies is most hygroscopic and the wood the least.

The cover of the big hill chillies is much more hygroscopic than that of the chillies of the plains.

It is further found that absorption of moisture increases with the increase of humidity of the surrounding air. This result is similar to that of the soils. The relation is not exactly linear. The rate of increase of weight by absorption of moisture is heigher in the beginning than at the end.

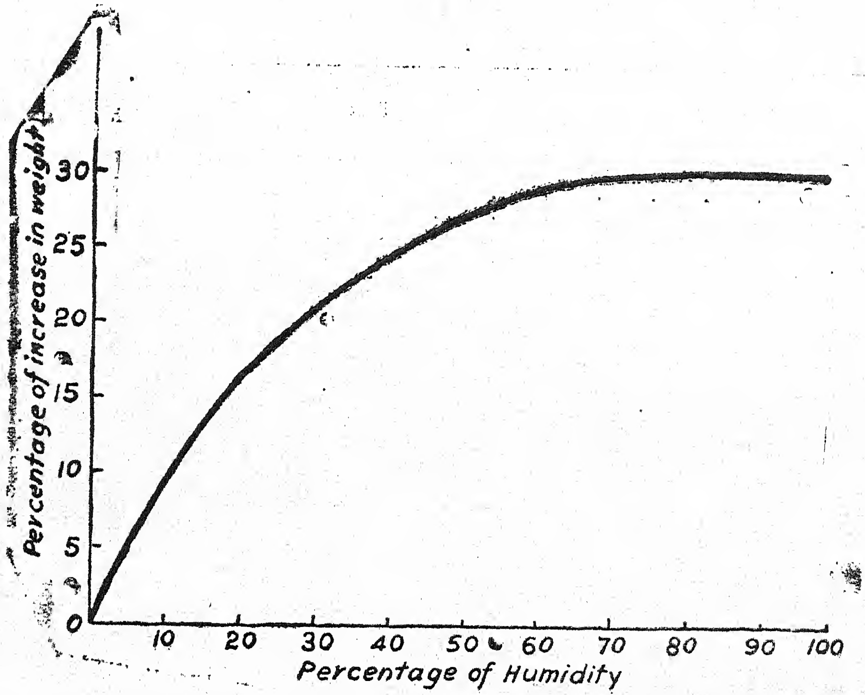

Fig. 1.

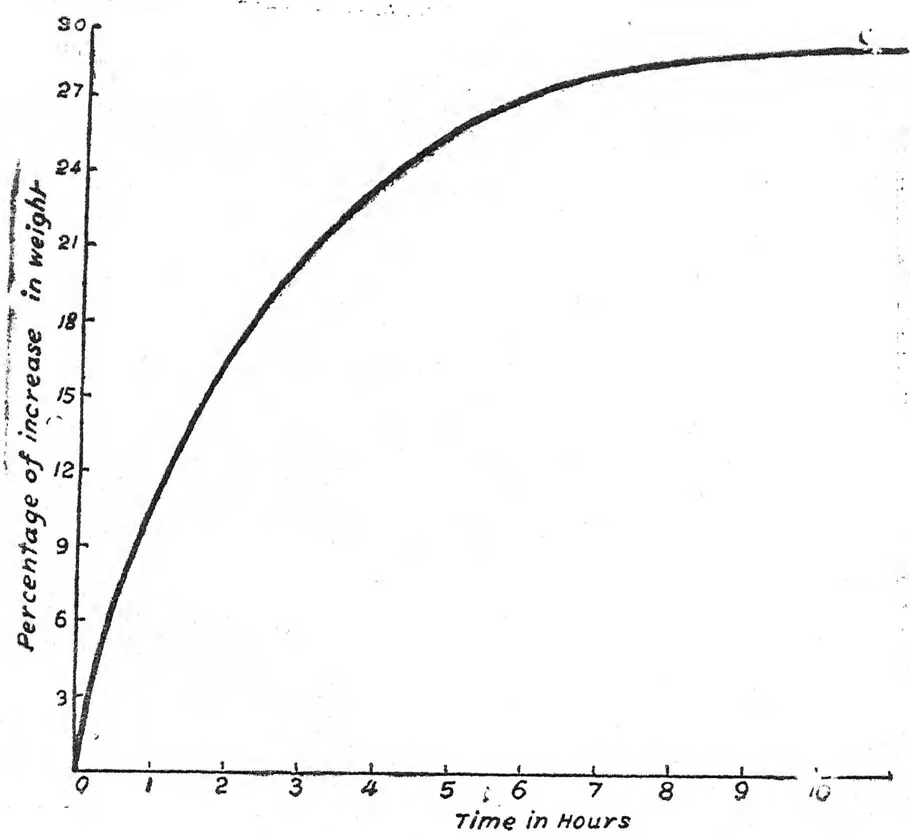

Fig. 2.

The rate of increase of weight due to the absorption of moisture with respect to time was also studied. It was found that this rate is not regular, but decreases with time. Figs. 1 and 2 show the general relation between the amount of absorption of moisture and time of exposure. The relation is not linear but logarithmic, like that of the soils.

The following conclusions have been derived from the above :

(i) The amount of moisture absorbed by the chillies varies according to their variety and the locality of their growth. The plant materials of the hills having high humidity are more hygroscopic than those of the plains.

(ii) The thick chillies absorb more moisture than the thin ones.

(iii) The power of absorption of the cover of the chillies is about twice that of their seeds.

(iv) The absorption power of wood is much less than that of the leaves and the absorption power of the leaves is less than that of the chillies.

(v) The powdered plant material is more hygroscopic than the plant material in natural form.

(vi) The chillies like the other plant materials behave like the soils, but they have higher power of absorption than the soils and some of the other plant materials, such as grains of wheat, paddy, *jawar* and *bajri*.

(vii) The absorption increases with the increase of relative humidity of the surrounding air.

(viii) The rate of absorption decreases with time. It is higher in the beginning than at the end.

(ix) The dry finely powdered plant materials produced by crushing of the young plants, when mixed with soils, increases their power of absorption. Thus it may reduce the frequency of irrigating the land, and may also help in dry farming.

(x) The age of the plant material decreases its absorption power. The older the material the less is its absorption power.

ACKNOWLEDGEMENTS

The author is indebted to Dr L. A. Ramdas for some of his reprints which he had so kindly presented to me for reference work. The author is also grateful to His Highness' Government, Patiala, for providing facilities to carry out their investigations in the Physics Research Laboratory, Mahendra College, Patiala.

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SELECTED ARTICLE

DEODORIZATION OF SYRUP MADE FROM KHANDSARI MOLASSES AND GUR*

By J. G. SHRIKHANDE and RAM DEV, Organic Chemistry Department, Imperial Institute of Sugar Technology, Cawnpore

(With one text figure)

IN view of the shortage of sugar, several enquiries were made by the manufacturers of syrups and aerated waters as to whether gur syrup could conveniently be made use of instead of sugar in this trade after in some way removing the gur odour. The typical gur odour or the aroma is mainly due to the presence of an essential oil in addition to other volatile organic bodies produced in gur due to micro-organic and enzyme activity during its storage. Caramel also to a certain extent affects the odour and also the taste. On purely chemical considerations the essential oil and volatile organic bodies like alcohol, acetone and low boiling organic acids could be removed by a current of steam. Preliminary experiments sweeping these bodies away from a gur syrup by a current of steam in the usual way gave some promising results. The results achieved by applying the usual method of steam distillation with some modification and chemical treatment to give syrup from gur and Khandsari molasses devoid of all gur aroma and flavour quite comparable to sugar syrup are embodied in this communication.

EXPERIMENTS

I. *Khandsari molasses.* 600 gm. of molasses after dilution with about 100 c.c. of water were shaken with nearly 6 gm. of kaolin for one hour and filtered. Kaolin removed some of the odour along with other adsorbable impurities. The filtrate was then steam distilled for nearly five hours. The distillate was collected to examine its contents. Table I summarizes the tests both in the distillate and the steamed syrup.

TABLE I

Physicial and a few chemical properties of the steamed molasses and distillates

	Colour	Odour	Reaction to litmus	pH	Titrable acidity
(1) Steamed molasses . .	Dark	light molassic	No marked change	6·80	(Gm. NaOH per 1000 c.c. distillate)
(2) Molasses steamed in presence of kaolin	,,	,,	,,	7·10	..
(3) Molasses steamed after kaolin, treatment	,,	,,	Acidic	5·50	..
Correspondin gdistillates					
(1) Distillate	Light orange	Penetrating	Acidic	4·40	0·135
(2) ,, ...	,,	,,	,,	4·70	0·128
(3) ,, ...	,,	,,	,,	4·67	0·128

All the three distillates decolourized acid permaganate and gave a red colouration with ferric chloride indicating the presence of aldehyde and acetic acid.

The speed of distillation was considerably improved by applying a gentle section. The quantity of distillate which took five hours to collect could now be collected within an hour ; this amounts to a saving in the steaming process.

* Reprinted from the XIV Proceedings Part II of the Sugar Technologists Association of India.

Effect of sulphite during steaming of Khandsari molasses on the odour of final syrup

From previous experience connected with the effect of sulphur dioxide on the colour of edible syrup from Khandsari molasses (1) it was considered desirable to see if sulphite had any direct effect on the colour and aroma of the steamed molasses. In order to test this sodium sulphite was added at the rate of 1 per cent on the weight of molasses to be steam distilled. The results are given in Table II.

TABLE II

Effect of sodium sulphite on steamed molasses

	Colour	Odour	pH
(1) Steamed molasses	Deep red	Molassic	Over 8·5
(2) Steamed molasses with Na_2SO_3	,,	Sweet like cane juice	Over 8·5
(3) Steamed molasses with Na_2SO_3 after kaolin treatment	Reddish	,,	8·5
Corresponding distillates			
(1) Distillate	Yellow orange	Pungent	4·4
(2) ,,	Deep orange	Less pungent	5·4
(3) ,,	Yellow orange	(1)	3·4

Results in Table II clearly indicate that sulphite during steaming effected the bodies responsible for the aroma of Khandsari molasses as the steamed molasses with sulphite treatment developed finally a sweet cane juice smell devoid of any molassic odour. It is possible that the essential oil responsible for the typical aroma was reduced by the sulphur dioxide produced from the added sodium sulphite. The colour too appears to have been bleached by the sulphur dioxide.

The steamed molasses was then treated with activated char and filtered through a layer of kaolin. Sulphur dioxide was then bubbled through the filtrate to effect further improvement in the colour of the syrup which was finally concentrated on a water bath to 82° Brix. The final syrup had a pleasant odour and a sweet taste unlike the molasses.

II. *Gur*. Gur was also treated on similar lines as the khandsari molasses to give deodorised syrup. The effect of direct steaming, after treatment with kaolin and subsequent steaming in presence of sulphite was the same as in the case of molasses. Table III contains some selected data.

TABLE III

Effect of different treatments and steam distillation on the odour of gur syrup

	Colour	Odour	pH
1. Steamed gur syrup	Red	Light gur	8·9
2. Steamed gur syrup with Na_2SO_3	Light red	Sweet cane juice	8·5
3. Steamed gur syrup with Na_2SO_3 after kaolin treatment	,,	,,	8·5
Corresponding distillates			
1. Distillate	Yellowish	Acrid and gur odour	3·4
2. ,,	Almost colourless	Almost odourless	4·5
3. ,,	,,	Odourless	4·5

It is clear from these tests that kaolin treatment followed by steam distillation in presence of sulphite completely deodorizes the syrups made from Khandsari molasses and gur. The *pH* values

of the steamed syrups and the corresponding distillates show that the acids accumulating during storage of gur and which are injurious to health are also removed by the same process.

After establishing that deodorized syrups are possible from Khandsari molasses and gur, it became necessary to study in some detail the effect of steaming for different periods on inversion of sucrose in the parent body, economics of the whole process and a few other factors connected with syrup manufacture. Accordingly experiments were conducted on gur to finalize the process as follows :

In the process adopted so far the sequence of treatments was (1) steaming, (2) sulphur dioxide treatment, and (3) concentration of the dilute syrup. All the three treatments necessarily cause inversion. To what extent inversion occurs is contained in Table IV.

TABLE IV

Inversion after each operation in deodorisation

(*Results expressed on 100 gm. dry gur*)

	In gur	In syrup after 1½ hr. steaming	After SO_2 treatment	Final syrup
Invert sugar	10·78	11·26	15·34	36·55

Inversion on steaming for 1½ hours is therefore almost negligible. Whatever inversion therefore occurs takes place during concentration to obtain the final syrup. This is of course due to the presence of sulphur dioxide.

Effect of different lengths of time of steaming on inversion

The results of this experiment are represented graphically in Fig I. It indicates that maximum inversion occurs during 1½ hours steaming. Any further steaming is therefore not advantageons from the point of view of inversion and deodorization.

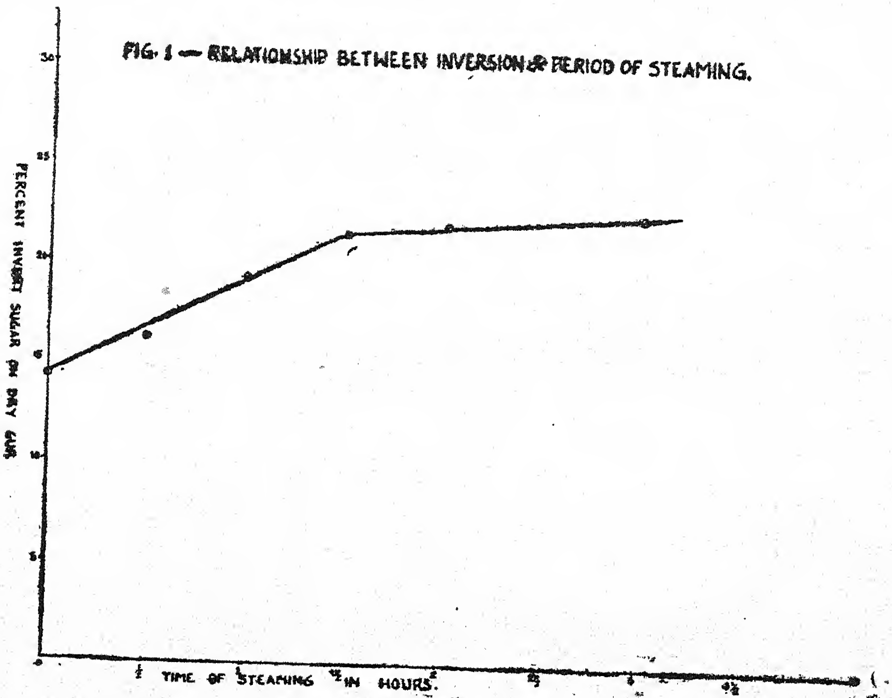

FIG. 1. Relationship between inversion and period of steaming

Systematic preparation and analysis of deodorized gur syrup

1000 gm. of gur of known analysis was made into a paste with 200 c.c. distilled water and was steam distilled for $1\frac{1}{2}$ hours applying gentle suction. After steaming the brix of the syrup fell down to 60°. The steamed syrup was then treated with activated char and filtered. Sulphur dioxide was bubled through the filtrate till the colour changed from reddish yellow to straw yellow. The dilute syrup was finally concentrated to a brix of nearly 80. During concentration vigorous stirring helps in the removal of sulphur dioxide. The final syrup had a golden yellow colour with a pleasant odour unlike that of gur. The syrup in fact appeared better than golden syrup made from cane sugar. Table V contains constants for the gur and the syrup made from it.

TABLE V

Analysis of gur and of the deodorized syrup from it

(*Results expressed on 100 gm. dry gur*)

—	Syrup	Gur
Yield of syrup	84·2	..
Brix	81	..
Sucrose	59·13	76·60
Reducing sugars	30·2	10·98
Ash	2·16	2·81
pH	5·8	6·0

From the above data the quantity of gur recovered amounted to 68·25 per cent. Some of the gur is undoubtedly lost due to handling in the various operations and other extraneous impurities in the gur which are removed during filtration of the steam syrup also contribute to this loss.

Although the various samples of deodorized syrup from gur contained nearly 60 per cent sucrose, they still did not crystallize on standing. This was unusual because almost every sample of golden syrup prepared from sucrose crystallized with 60 per cent of sucrose in it. A search was, therefore, made for the cause in view of its great technical importance on analysis of a number of deodorized gur syrups which had shown signs of crystallization and stability in its fluidity it was found that sulphur dioxide was the chief agent affecting this phenomenon. From these investigations it may be said that sulphur dioxide serves three purposes (1) improves the colour of the syrup, (2) acts as a sterilizing agent, and (3) prevents crystallization even in the presence of large concentration of sucrose in the syrup.

Effect of sulphur dioxide on crystallization and stability of the syrup

The third point needed further investigation to ascertain the limits of sulphur dioxide concentration which would prevent crystallization in the syrup. Accordingly certain samples of syrup which remained fluid for a number of months and those which had crystallized on standing were examined for their sulphur dioxide content by a new method to be described elsewhere. A sample which did not crystallize for three months when freed of its sulphur dioxide by aeration for 2 hours and subsequent treatment with kaolin crystallized almost immediately. This clearly demonstrates that sulphur dioxide was mainly responsible for keeping this syrup in the fluid state.

Sulphur dioxide content of five representative samples recorded in Table VI gives an idea of the range of sulphur dioxide which may be useful in preventing crystallization. From the data presented a final concentration of about 0·7 per cent sulphur dioxide should be sufficient to prevent crystallization in a syrup containing sucrose to the extent of nearly 60 per cent. Concentration of sulphur dioxide will be considerably reduced when these syrups are consumed in dilute forms and in small quantities. Further in the aerated water industry where the deodorized gur syrups can be used with advantage in coloured drinks, whatever sulphur dioxide is introduced in the drink will be displaced by the charge of carbon dioxide. The question of the toxicity of sulphur dioxide in the syrup therefore does not arise.

TABLE VI

Effect of sulphur dioxide concentration on crystallization

	Sample which did not crystallize for 6 months	Sample which did not crystallize for 4 months	Sample which did not crystallize for 2 months	Sample which crystallized in	
				15 days	10 days
Per cent sulphur dioxide in syrup	2·21	1·39	0·78	0·57	0·27

Practical importance of the investigation. (1) Those who have a dislike for gur flavour can use gur in the form of deodorized syrup which will be cheaper than golden syrup, (2) during sugar shortage the industries concerned can make use of deodorized gur syrup in the manufacture of table syrup, *sharbats* and aerated waters, and (3) gur which might have deteriorated during storage can be profitably utilized.

Cost of production

(1) 10 md. gur (deteriorated) of light colour @ Re. 1 per md.	= Rs.	10	0	0
(2) Steam distillation and final concentration	= Rs.	5	0	0
(3) Kaolin @ 5 annas per lb.	= Rs.	2	8	0
(4) Sulphur dioxide	= Rs.	5	0	0
(5) Overhead charges	= Rs.	10	0	0
Syrup yield from 10 md. gur equivalent to 8 md. nearly	= Rs.	32	8	0

Cost per lb. of deodorized syrup = nearly 1 anna.

SUMMARY

A method of preparing deodorized syrup from Khandsari molasses and gur has been described. The process in brief consists of making a paste of gur in water of the consistency of a porridge and then steam distilling it for one hour and a half. By this time all the volatile bodies present as impurities in the molasses or gur are swept off. The steamed syrup is then filtered through a layer of kaolin which absorbs any other impurities thereby improving the colour and the colour of the syrup still further. The colour of the syrup is then finally improved by drawing a stream of sulphur dioxide through it. Final syrup is then obtained by concentration in basins or under reduced pressure.

The effect of sulphur dioxide on crystallization of syrups and the minimum quantity of this gas which prevents crystallization has been determined.

By this process gur which has deteriorated during storage can be profitably utilized by converting it into deodorized syrup.

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REVIEW

Some British Books on Agriculture, Nutrition, Forestry and Related Sciences 1939-1945—List compiled by H. M. Bedington.

(Imperial Agricultural Bureaux Joint Publication No. 11. Published July 1946. Price : 3s., Pp. 36)

THIS is a very useful publication embracing references on agriculture, nutrition, forestry and related biological and other sciences published during 1939 to 1945. A subject index has been provided so that one can easily find out the work he is interested in. It will be of great service to the workers concerned.—I.C.

PLANT QUARANTINE NOTIFICATIONS

Notification No. F.3-1/46-PP., dated the 17th August 1946, of the Government of India in the Department of Agriculture

IN exercise of the powers conferred by Sub-section (1) of section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following further amendment shall be made in the order published with the notification of the Government of India in the late Department of Education, Health and Lands No. F.320/35-A., dated the 20th July 1936, namely :—

In paragraph 8B of the said Order, after the word " Burma " the words " or the Kalat State " shall be inserted.

Notification No. F.3-5/46-PP., dated the 16th September 1946, of the Government of India in the Department of Agriculture

In exercise of the powers conferred by Section 4C of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following amendment shall be made in the notification of the Government of India in the Department of Agriculture, No. D.22-1/46-P., dated the 16th February 1946, namely :—

In the said notification, for the words " British India " the words " the Province of Madras " shall be substituted.

MGIPC—M—III-1-17—29-4-48—600.

ORIGINAL ARTICLES

A STUDY ON THE EFFECT OF CULTURAL FACTORS IN TRANSPLANT PADDY ON THE BEHAVIOUR OF SOME PLANT CHARACTERS INFLUENCING THE YIELD

By S. Hedayetullah, K. P. Roy and S. Sen, Botanical Section, Agricultural Research Station, Dacca

(Received for publication on 30 January 1946)

(With one text-figure)

PRINCIPALLY there are two methods of paddy cultivation which are practised all over the paddy growing tracts in the world. One of them is sowing of seeds directly in the field by broadcasting and the other is transplanting of seedlings which are raised in nurseries. In Bengal the former method is practised for particular classes of paddy (highland and lowland *Aus* and long stemmed paddy) depending on particular situations of the field. The cultivation of the main bulk of the paddy crop of Bengal is done on semi-low land.

A detailed analysis brings out that the important cultural factors which come into play in the transplant method of cultivation are: (i) Age of seedling at the time of transplantation, (ii) Date of transplantation, (iii) distance between transplanted seedlings, (iv) Number of seedlings transplanted per hole in the field, and (v) Treatment of soil both in the seed-bed and transplant-field.

The object of the present experiment has been to find as to how or to what extent variations in a few of the cultural factors impinge on the various yield-contributing characters of the rice plant to produce a significant impression.

Material and method

The experiment was undertaken with a view to study the effects of three cultural factors, namely, (i) strains of winter rice of varying duration of life, (ii) varying number of seedlings planted per hole, and (iii) varying degrees of spacing between holes, on the final expression of the following plant characters: (1) Number of fertile tillers per plant, (2) Number of sterile tillers per plant, (3) Height of the plant, (4) Length of panicle, (5) Extent of exertion of panicle, (6) Total number of spikelets (or grains) per panicle, (7) Ratio of full spikelets to unfilled spikelets per panicle, (8) Weight of 100

Variants under the three cultural factors were as follows:

I. Rice strains:

(1) *Latisal* (span of life, 135 days)*

(2) *Tilakkachari* (span of life, 150 days)*

II. Number of seedlings planted per hole:

(1) Single

(2) Local (3 to 4)†

III. Spacings:

(1) 6 inches (15·24 cm.)

(2) 9 „ (22·86 c.m.)

(3) 12 „ (30·48 cm.)

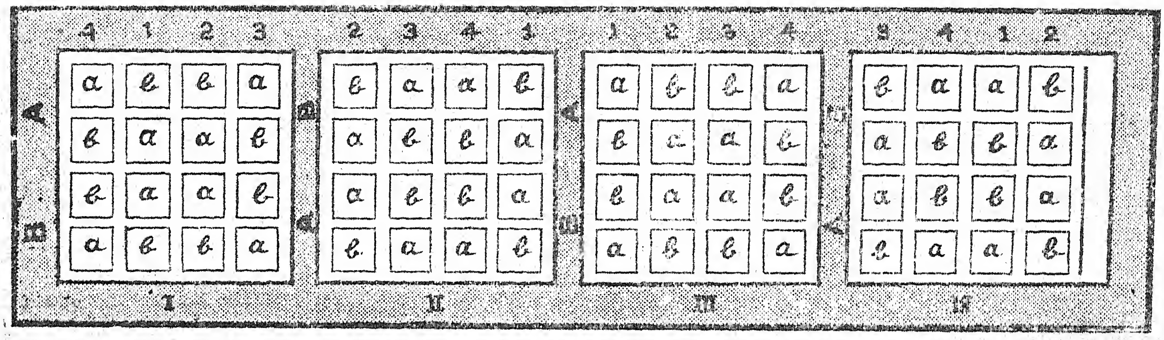
(4) 15 „ (38·10 cm.)

*Including nursery life of 35 days.

†The latter practice is in vogue among the local cultivators and has therefore been designated in the paper as 'Local'.

Taking these eight factorial variants in combination there were 16 (or $2\times2\times4$) different treatments. Each of these treatments was replicated four times in four blocks giving a total of 64 unit plots. The area of each unit plot was 81 sq. ft. (9 ft.$\times$9 ft.) with 2 ft. wide alleys running between them. The experiment was laid out on a plot of land in a semi-low ravine having clay loam soil as is typical of the transplant-*Aman* rice lands of Madhupur jungle tract in the district of Dacca. The selected plot was remarkably uniform in fertility as was ascertained from the previous observations of crop performance on it.

The design adopted for the experiment is one of the split plot type with strip treatments. There are four different plot sizes: (1) Seedling treatment plots in horizontal strips, (2) Spacing treatment plots in columns, (3) Seedling $\times$ spacing treatment plots consisting of half columns, and (4) Ultimate sub-plots for varieties. The layout of the experiment is shown in Fig. 1.



A = 1 Seedling
B = 3-4 Seedlings.

1 = 6 in.
2 = 9 in.
3 = 12 in.
4 = 15 in.

a = *Latisal*
b = *Tilakkachari*

Area of sub-plot = 9 ft. $\times$ 9 ft.
Footpath round the sub-plot = 2 ft.

FIG. 1. Diagrammatic plan of the experiment.

Seeds of both the varieties were sown in seed-beds on the 16th June and seedlings were transplanted on the 21st July, their age at that time being five weeks.

When the plants were almost mature a row of marginal plants was rejected from all the sub-plots and among the remaining plants in each 20* were labelled at random for making observations on different characters. The position of each of these 20 selected plants in each sub-plot was determined with the help of Tippet's random number series.

The following observations were recorded in the field on the 20 labelled plants and the average per plot was calculated from these 20 observations.

(i) Number of fertile tillers in each plant (i.e. in each hole).

(ii) Number of sterile† tillers in each plant (i.e. in each hole).

(iii) Height of the plant in centimetres from the ground level to the tip of the flag-leaf on the main (tallest) tiller.

(iv) Length of panicle measured in centimetres on the main (tallest) tiller from the lowermost node of the rachis to the tip of the panicle.

(v) Extent of exertion measured in centimetres on the main (tallest) tiller (from the juncture of the flag leaf to the lowermost node of the rachis).

(vi) Number of spikelets per panicle on the main (tallest) tiller.

*In the experiment different numbers of plants have been put in a hole and, as such, it would be more correct to designate " a plant " as " plant in a hole ". But for the sake of convenience we have, on most occasions, stated in terms of plants rather than plant-holes, although we have meant the latter unless of course specifically mentioned.

†Tillers that are produced quite late in the life of a plant do not bear ears and have therefore been termed as sterile.

After the above observations were recorded these 20 plants were allowed to attain full maturity in the field and thereafter were harvested for further study in the laboratory and for weighment of the final produce of grain and straw. To prevent any loss of grain by shattering necessary precautions were taken by enclosing the ears of these plants (unsevered from the straw) in small paper bags at the time of harvesting.

The following observations on the grain were taken in the laboratory.

(i) The length, breadth and thickness of 10 grains taken at random from each bag (i.e from each of the 20 labelled plants) were measured in millimetres with screw-micrometre. The average length, breadth and thickness of grain for each plant were calculated from the measurements of 10 grains of a plant; and from 20 different measurements so obtained, each of length, breadth and thickness, the plot averages were calculated. The product of these three dimensions gave the volume of grain for the plot.

(ii) Weight of 100 grains: Weights were recorded of 100 full grains in the ten random lots, taken from each of the 64 bags containing the grains of all the 20 plants from a plot. An idea of the average weight of a unit number of grains in each treatment could be had from these weights.

STATISTICAL ANALYSIS OF DATA AND DISCUSSION OF RESULTS

The analyses of variances for all the characters studied are given in Table I.

TABLE I

Analyses of variances

Sources of variance	Degrees of freedom	VARIANCES								
		(i) No. of fertile tillers per plnat	(ii) No. of sterile tillers per plant	(iii) Height of plant	(iv) Length of panicle	(v) Extent of exertion	(vi) No. of full spikelets per panicle	(vii) Ratio of full to unfilled spikelets per panicle	(viii) Weight of 100 grains	(ix) Volume of grain
Block	3	2·19	0·49	8·18	16·17	1·28	189·54	2·98	0·01	3·20
No. of seedling	1	4·17	0·01	109·46	22·66	0·46	2278·04†	12·25	0·00	4·29
Error	3	0·49	0·31	104·96	20·78	1·16	40·00	1·58	0·01	34·47
Spacing: Linear	1	1069·64†	5·82†	151·14†	12·48†	2·34	10798·81†	0·60	0·002	0·24
Spacing: Quadratic	1	7·45	0·00	3·85	5·55‡	0·02	398·85	0·02	0·00	0·12
Spacing: Cubic	1	1·40	0·03	158·65†	1·07	0·04	305·59	2·31	0·005	1·51
Error	9	2·21	0·54	12·80	0·98	0·76	157·25	5·69	0·01	18·88
Seedling × Spacing	3	5·76†	0·44†	2·37	3·30	0·53	151·73	5·70	0·00	6·16
Error	9	0·37	0·04	8·90	1·24	1·50	307·70	2·91	0·0033	10·30
Variety	1	78·36†	0·75	3890·64†	6·02	123·88†	4297·05†	149·51†	1·33†	2109·45†
Variety × Seedling	1	3·44	0·02	3·59	16·76‡	0·94	18·99	0·00	0·00	18·83
Variety × Spacing	3	5·24†	0·06	3·40	1·39	0·69	41·60	4·29	0·00	6·11
Variety × Seedling × Spacing	3	1·07	0·03	9·02	0·52	2·48	57·24	10·58	0·00	12·74
Error	24	1·06	0·27	12·82	3·74	0·91	235·01	5·14	0·01	17·02
Total	63									

†Significant at 1 per cent level
‡Significant at 5 per cent level

(i) *Number of fertile tillers per plant*

This is perhaps the most important of the factors which make up the yield of the plant. The primary results are shown in Table II and significant interactions in Tables III and IV.

TABLE II

Average number of fertile tillers per plant

No. of seedling	No. of fertile tillers	Spacing	No. of fertile tillers	Variety	No. of fertile tillers
Single	9·78	6 in.	4·96	*Latisat.*	11·14
Local	10·29	9 in.	7·67	*Tilakkachari.*	8·93
		12 in.	11·72		
		15 in	15·80		
Mean	10·04		10·04		10·04
S.E.	0·12		0·37		0·18
C.D. at 5 per cent	0·56		1·19		0·53

TABLE III

Number of seedling × *spacing* (*average number of fertile tillers per plant*)

No. of seedling	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Single	5·00	7·88	11·58	14·67	9·78
Local	4·92	7·46	11·87	16·93	10·29
Mean	4·96	7·67	11·72	15·80	10·04

S.E.=0·22 *C.D.* at 5 per cent=0·69

TABLE IV

Variety × *spacing* (*average number of fertile tillers per plant*)

Variety	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Latisal	5·49	8·39	13·12	17·56	11·14
Tilakkachari	4·43	6·94	10·33	14·03	8·93
Mean	4·96	7·67	11·72	15·80	10·04

S.E.=0·36 *C.D.* at 5 per cent=1·06

Number of seedling. This factor has got no significant effect on the number of fertile tillers per plant. Table II shows that as was reasonably expected the number of fertile tillers in the local method of planting (3 or 4 plants) is slightly greater than that in the 'single' (one plant). If, however, the tiller per plant (not per hole) is compared in both the cases, we find that 'single' which produces 9·78 tillers is much better than 'local' producing nearly 2·91 tillers per plant. Our results concur with those of Jack [1921], Calvo [1927] and Haigh [1938].

Spacing. Number of fertile tillers per plant varies directly with spacing, statistically, 15 in.> 12 in.> 9 in.> 6 in. This decrease in tiller-number with the decrease in spacing is apparently the result of keen competition between adjacent plants for air, light, soil nutrients, etc., due to crowding. Therefore a greater distance between plant holes provides a more congenial environment for the better growth and development of the plant as partly reflected in the production of a large number of tillers.

The relation between spacing and the number of fertile tiller per plant as well as per acre is shown in Table V.

TABLE V

The relation between spacing and the number of fertile tillers per plant

Spacing	No. of tillers per plant	Ratio	Theoretical No. of plant holes per acre	Ratio	Theoretical No. of tillers per acre	Ratio
6 in.	4·96	1·00	174240	1·00	864230·40	1·00
9 in.	7·67	1·55	77440	0·44	593964·80	0·68
12 in.	11·72	2·37	43560	0·25	510523·20	0·59
15 in.	15·80	3·19	27878	0·16	440472·40	0·51

It may be seen from Table V that if we take 6 in. of spacing as our standard there is, for an increase of every three inches over it up to 15 in., a corresponding increase in the number of fertile tillers in the order of 1·00 : 1·55 : 2·37 : 3·19. But the number of plant holes per acre commencing from 6 in. upwards being in the descending order of magnitude as 1·00 : 0·44 : 0·25 : 0·16, the total number of fertile tillers per plot also shows correspondingly a similar trend of decrease. It will be discussed hereafter if this fall in the number of fertile tillers per acre has any significant bearing on yield.

Variety. Figures in Table II clearly show that *Latisal* produces a greater number of fertile tillers than *Tilakkachari*. From this one may naturally assume that *Latisal* was a better yielder of the two. But this is not so. From the point of yield they were significantly at par. The factors responsible for this levelling up effect will be discussed later in this paper.

Interactions. It is seen from the above tables that the combination of local method of planting with 15 in. spacing in one case and that of *Latisal* with 15 in. spacing in the other give the maximum number of fertile tillers.

(ii) *Number of sterile tillers per plant*

With regard to this character only an interactional effect between the number of seedling and spacing is significant, but since none of the primary effects is significant no importance can be attached to the observed interaction.

(iii) *Height of plant*

The primary effects are shown in Table VI.

TABLE VI

Average height of plant in centimetres

No. of seedling	Height	Spacing	Height	Variety	Height
Single	131·36	6 in.	135·63	*Latisal* . .	124·87
Local	133·98	9 in.	131·13	*Tilakkachari* .	140·46
		12 in.	133·71		
		15 in.	130·19		
Mean	132·67		132·67		132·67
S.E.	1·81		0·89		0·63
C.D. at 5 per cent . .	8·15		2·86		1·85

Number of seedling. The plant in the 'local' is taller than in the other method of planting, the difference between the two being, however, too small to be taken into consideration.

Spacing. There is a definite tendency of the plants decreasing in height with the increase in spacing. The two intermediate spacings, i.e. 9 in., and 12 in. are, however, at par from the point of significance.

Variety. There is a great difference between the two varieties, *Tilakkachari* being much taller than *Latisal.*

Interaction. None of the interactions is significant.

(iv) *Length of panicle*

This is an important factor contributing towards the yield per tiller since the number of spikelets on a panicle depends on the length of the latter. It is only in a longer panicle that a larger number of branches and a larger number of spikelets can be accommodated.

The primary effects and the significant interaction are shown in the Tables VII and VIII respectively.

TABLE VII

Average length of panicle (in cm.)

No. of seedling	Length of panicle	Spacing	Length of panicle	Variety	Length of panicl
Single	25·16	6 in.	23·62	*Latisal*	24·87
Local	23·97	9 in.	24·83	*Tilakkachari*	24·26
		12 in.	24·88		
		15 in.	24·92		
Mean	24·56		24·56		24·56
S.E.	0·81		0·25		0·34
C. D. at 5 per cent	3·63		0·79		1·00

TABLE VIII

Number of seedling × variety (average length of panicle in cm.)

Variety	No. of seedling: Single	No. of seedling: Local	*Mean*
Latisal	24·95	24·79	24·87
Tilakkachari	25·36	23·15	24·26
Mean	25·16	23·97	24·56

S.E.=0·48 *C.D.* at 5 per cent=1·41

Number of seedling. The effect of this factor cannot be regarded as sufficient from the statistical point of view.

Spacing. The length of panicle gradually increases with the increase in the distance between adjacent seedlings, 6 in. producing the shortest and 15 in. the longest inflorescence. The difference between 6 in. and each of the other three spacings is significant but there is nothing to choose between 9 in., 12 in. and 15 in. Haigh [1938] obtained somewhat similar results with his three-plant treatments only. It is interesting to note that as compared to the vegetative portion of the axis of the plant (Table VI) the reproductive portion (rachis) is affected in a reverse way by wider spacing so far as the length is concerned.

Variety. *Latisal* appears to be slightly superior to the other variety, although the difference is not significant.

Interactions. With regard to the number of seedling × variety the longest panicle is produced in *Tilakkachari* 'single' and shortest in *Tilakkachari* 'local'.

(v) *Extent of exertion*

The primary effects are shown in Table IX.

TABLE IX

Average extent of exertion (in cm.)

No. of seedling	Exertion	Spacing	Exertion	Variety	Exertion
Single	0·06	6 in.	0·39	*Latisal* . .	1·54
Local	0·23	9 in.	0·22	*Tilakkachari* .	1·24
		12 in.	0·11		
		15 in.	0·14		
Mean	0·15		0·15		0·15
S.E.	0·19		0·15		0·17
C.D. at 5 per cent. . .	0·86		0·49		0·49

Number of seedling. The exertion is slightly more in the case of the 'Local' than in the other, although the difference is not significant.

Spacing. There is nothing to choose between the four different spacings.

Variety. This is the only factor which produces significant effect on the character in question. The extent of exertion is 1·54 cm. in *Latisal* and —1·24 cm. in *Tilakkachari.* The panicle in the latter is partly enclosed by the flag leaf and thereby gives a *minus* value to its measurement.

Interactions. None of the interactions is significant.

(vi) *Number of full spikelets per panicle:*

This is a very important factor contributing towards the yield per tiller.

The primary effects are shown in Table X.

TABLE X

Average number of full spikelets per panicle

No. of seedling	No. of spikelets	Spacing	No. of spikelets	Variety	No. of spikelets
Single	139·26	6 in.	112·39	*Latisal* . .	125·10
Local	127·33	9 in.	132·91	*Tilakkachari* .	141·49
		12 in.	138·67		
		15 in.	149·19		
Mean	133·29		133·29		133·29
S.E.	1·12		3·14		2·70
C.D. at 5 per cent . .	5·03		10·03		7·89

Number of seedling. This factor has got a profound influence on the character in question, the 'single' being significantly better than the other.

Spacing. There is a progressive increase in the number of full spikelets with the increase in spacing, 15 in. giving the maximum followed by 12 in., 9 in. and 6 in. in that order. The first one is significantly superior to all other; 12 in. and 9 in. are both better than 6 in. but they themselves are at par. These results concur with those of Haigh's [1938] three-plant treatments only and not with the others. Hector's [1920-21] findings are also more or less similar to ours.

Variety. The results obtained with regard to the effect of variety shown in Table X appear somewhat peculiar if a comparison is made of these with the results obtained for the length of panicle. Though there is no significant difference between the lengths of panicle of the two varieties, the number of full spikelets is significantly more in *Tilakkachari*. This is apparently due to the presence of a greater number of branches or a closer setting of the spikelets or both in the panicle of *Tilakkachari* than that of *Latisal*.

Interactions. None of the interactions is significant.

(vii) *Ratio of full to unfilled spikelets per panicle*

The primary effects are shown in Table XI.

TABLE XI

Average ratio of full to unfilled spikelets per panicle

No. of seedling	Ratio	Spacing	Ratio	Variety	Ratio
Single	6·31	6 in.	6·07	*Latisal*	7·40
Local	5·43	9 in.	5·68	*Tilakkachari*	4·34
		12 in.	6·10		
		15 in.	5·64		
Mean	5·87		5·87		5·87
S.E.	0·22		0·60		0·40
C.D. at 5 per cent	1·00		1·91		1·17

Number of seedling. The effects of different planting methods are not sufficient to stand a statistical comparison.

Spacing. The different spacings also do not influence the character in question significantly.

Variety. This is the only factor producing a significant effect on the character, which is more in *Latisal* than in *Tilakkachari*. This is a varietal character very little affected by the two cultural factors.

Interactions. None of the interactions is significant.

(viii) *Weight of 100 grains*

The primary effects are shown in Table XII.

TABLE XII

Average weight of 100 grains (*in gm.*)

No. of seedlings	Weight	Spacing	Weight	Variety	Weight
Single	2·95	6 in.	2·93	*Latisal*	2·79
Local	2·93	9 in.	2·92	*Tilakkachari*	3·08
		12 in.	2·95		
		15 in.	2·94		
Mean	2·94		2·94		2·94
S.E.	0·02		0·02		0·02
C.D. at 5 per cent	0·08		0·08		0·05

Number of seedling. The effects of the two different methods of planting on the character in question are very small and cannot be compared statistically.

Spacing. This factor also has not produced any significant effect on the weight of 100 grains. These results tally with those obtained by Hector [1920-21].

Variety. Varietal effects are however prominent in that the grains of *Tilakkachari* are significantly heavier than that of *Latisal*. This is a varietal character and is very little influenced by the two cultural factors.

Interactions. None of the interactions is significant.

(ix) *Volume of grain*

The primary effects are given in Table XIII.

TABLE XIII

Primary effects

Average volume of grain—length × breadth × thickness—in c. mm.

No. of seedling	Volume	Spacing	Volume	Variety	Volume
Single	61·50	6 in.	61·35	*Latisal* . .	55·50
Local	60·98	9 in.	61·11	*Tilakkachari* .	66·98
		12 in.	61·46		
		15 in.	61·05		
Mean	61·24		61·24		61·24
S.E.	1·04		1·09		0·73
C.D. at 5 per cent . .	4·67		3·47		2·13

Variety. This is the only factor which produces a significant effect on the volume of grains. As may be seen in Table XIII, grains of *Tilakkachari* are much bigger in size than those of *Latisal.* The character is a varietal one and is not significantly affected by the two cultural factors.

(x) *Yield of final produce*

With a view to ascertain as to how far the detailed observations made on the effect of the cultural factors on the yield contributing characters of the plant compare with the final produce, the weights of the 20 plants under observation were recorded for the grain and straw yields.

The analysis of the yield data are given in Table XIV.

TABLE XIV

Analysis of variance of grain and straw yields of 20 plants

Sources of variance	Degrees of freedon	Variance	
		Grain	Straw
Block	3	1·06	19·27
No. of seedling	1	7·66	6·28
Error	3	7·02	6·18
Spacing . . Linear	1	3883·61*	6453·47*
Spacing . . Quadratic	1	11·79	0·00
Spacing . . Cubic	1	19·37	113·57
Error	9	4·72	15·53
Spacing × seedling	3	1·48	83·18†
Error	9	1·82	19·82
Variety	1	10·42	2266·81*
Variety × seedling	1	0·21	0·05
Variety × spacing	3	1·96	94·42†
Variety × spacing × seedling	3	0·66	48·75
Error	24	2·81	26·23
Total	63		

*Significant at 1 per cent level

†Significant at 5 per cent level

The most interesting point in the above analysis is the extremely insignificant variance due to blocks. The same feature is also observable in analysis of variance with respect to other plant characters under study. This confirms the fact that the plot selected for the purpose of this investigation was remarkably uniform in constitution and fertility.

It may be seen from Table XIV that in respect of the grain yield, of all the treatments, spacing only has produced significant effects (at 1 per cent level), whereas for the straw not only both spacing and variety are significant at the same level but there is also an interactional effect of the first order between them as well as between spacing and seedling at 5 per cent level each.

Table XV shows the primary effects on the yield of grain and straw.

TABLE XV

Primary effects

Mean yield of grain and straw of 20 plants in oz.

No. of seedling	Yield		Spacing	Yield		Variety	Yield	
	Grain	Straw		Grain	Straw		Grain	Straw
Single	16·87	26·34	6 in.	6·75	13·78	*Latisal*	16·12	20·71
Local	16·18	26·97	9 in.	11·88	20·37	*Tilakkachari*	16·93	32·61
			12 in.	20·32	32·92			
			15 in.	27·16	39·54			
Mean	16·53	26·65		16·53	26·65		16·53	26·65
S.E.	0·46	0·44		0·54	0·98		0·30	0·91
C.D. at 5 per cent	2·06	1·97		1·72	3·13		0·87	2·65

Number of seedling. The results show that in our experiment the treatment 'No. of seedlings' could not at all influence the yield of grain or straw. Thus our observations on this point are at variance with those of Haigh [1938].

Variety. There is some difference in grain yields between *Latisal* (early) and *Tilakkachari* (late) in favour of the latter but it cannot be established statistically, whereas for straw yields the difference is marked.

Spacing. The four spacing treatments, as will be seen from Table XV, have all produced definite effects on both grain and straw yields. Statistically they are in the order of 15 in.> 12 in.> 9 in.> 6 in.

These results are in agreement with those of various other investigators who have worked elsewhere on this point. Some of these workers have also asserted that although wider spacing is beneficial so far as yield per plant is concerned there is a limit to the spacing which can be utilized by the plants to their advantage. Perhaps it is true, but in our experiment the highest yield per plant has been obtained with 15 in. (38·10 cm.) which is the maximum spacing considered. It is therefore not possible to state whether the yield can be increased further or not by increasing the spacing beyond 15 in.

The average yields of grain and straw per plant (per hole) in this experiment which can be calculated from the figures in Table XV are given below :

—	Grain (oz.)	Straw (oz.)
6 in.	0·34	0·69
9 in.	0·59	1·02
12 in.	1·01	1·65
15 in.	1·35	1·98

The above figures show that the widest spacing is the beat, both for the yields of grain and straw per plant. Though the yield per plant increases with the increase in spacing, the number of plants per unit area gets less and less, and, since this decrease is in a greater proportion than the increase in yield per plant, the total yield of the area falls. This feature is shown in Table XVI, wherein the yield per acre is calculated by multiplying the yield of an individual plant (hole) by the theoretical number of plants (holes) per acre. It will be seen that the order of merit is exactly reversed, the widest spacing giving the poorest yield per acre and the closest spacing the best.

TABLE XVI

The number of plant and yield per acre

Spacing	Theoretial No. of plants per acre	Yield per plant in oz.		Theoretial yield per acre in oz.	
		Grain	Straw	Grain	Straw
6 in.	174240	0·34	0·69	59241·60	120225·60
9 in.	77440	0·59	1·02	45689·60	78988·80
12 in.	43560	1·01	1·65	43995·60	71874·00
15 in.	27878	1·35	1·98	37635·30	55198·44

It is seen that the number of plants per acre is of very great importance for the determination of yield per acre. With wider spacing the yield of individual plants definitely increases, and, this is due largely to the production of greater number of tillers and to some extent to the production of greater number of grains per panicle. But the fall in the number of plants per acre is not compensated by the increase in yield per plant. Our results are in agreement with those obtained by Ramiah [1937] and Haigh [1938]. Chakravarty *et al.* [1936] working with plot yields only also arrived at similar conclusions.

Of the two varieties, it was first thought that *Latisal* would prove to be a better yielder since it produces a significantly greater number of fertile tillers. But Table XV shows that it is actually not so. This anomaly could be explained by the results obtained in the case of 'number of full spikelets per panicle' and 'weight of unit number of grains'. It may be seen that the number of grains produced per panicle as well as the weight of unit number of grains in *Latisal* are significantly less than in the other and, as such, the initial advantage gained by the former on account of its production of more fertile tillers is completely lost. Haigh [1938] claims that the number of tillers matured is the limiting factor in the determination of the yield per plant and that the fluctuations in the factors which made up the yield per tiller, viz. number of grains per tiller and weight of individual grains are not sufficient to upset the influence of tiller number. The results obtained by us do not support such a claim.

Interactions. The significant interactions of the first order are given in the Tables XVII and XVIII.

TABLE XVII

Spacing × Seedling

Mean yield of straw of 20 plants per plot in oz.

No. of seedling	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Single	14·76	21·37	33·42	35·83	26·34
Local	12·81	19·37	32·44	43·26	26·97
Mean	13·79	20·37	32·93	39·54	26·66
S.E.=1·57					
C.D. at 5 per cent . .	5·01				

TABLE XVIII

Variety × Spacing

Mean yield of straw of 20 plants per plot in oz.

Variety	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Latisal	9·74	16·61	25·63	30·85	20·71
Tilakkachari	17·84	24·14	40·23	48·22	32·61
Mean	13·79	20·37	32·93	39·54	26·66
S.E.=1·81					
C.D. at 5 per cent	5·27				

SUMMARY

An experiment was conducted with two varieties of paddy, *Latisal* (early) and *Tilakkachari* (late), to study the effects of two cultural factors, viz. different numbers of seedling per hole, and different spacing between seedlings on some characters of agricultural importance. There were two different numbers of seedlings, single and local (3—4), and four different spacings 6 in., 9 in., 12 in., 15 in. The results obtained for different characters are summarized below :

(i) Number of fertile tillers per plant. The number of seedlings has no effect on this character. 15 in. spacing produces the highest number of fertile tillers followed by 12 in., 9 in. and 6 in. respectively. *Latisal* produces more fertile tillers than the other variety.

(ii) Number of sterile tillers. No factor, not even varieties, has any effect on the number of sterile tillers.

(iii) Height of plant. None of the cultural factors has any appreciable effect on the height of plant. Plants in *Tilakkachari* are, however, taller.

(iv) Length of panicle. The widest spacing 15 in. produces the longest panicle followed by 12 in., 9 in. and 6 in. respectively. There is no significant difference within the last three. There is no differential effect of the number of seedlings nor of the varieties under observation on this character.

(v) Extent of exertion of panicle. *Latisal* is more exerted than the other variety. The character is not affected by the two cultural factors.

(vi) Number of full spikelets per panicle. The number of full spikelets is more in the 'single' than in 'local' planting. There is a gradual increase in the number of this per panicle with the increase in spacing. Of the two varieties, *Tilakkachari* has a larger number of full spikelets per panicle.

(vii) Ratio of full spikelets to unfilled spikelets. This ratio is more in *Latisal*. The two cultural factors have no appreciable effect on it.

(viii) Weight of grain. The weight of grain in *Tilakkachari* is more than in *Latisal*. The cultural factors do not affect the character appreciably.

(ix) Volume of grain. *Tilakkachari* has a larger volume of grain than *Latisal*. The character remains unaffected by the cultural factors.

(x) Yield of final produce. Of the three factors under consideration, spacing only has produced a marked effect on both grain and straw yields. Significantly the four spacings are in the order 15 in.> 12 in.> 9 in.> 6 in. These differential effects could only be established for individual plant yields but when the yield per unit area is considered the respective position of the series of spacings gets reversed. In the case of straw, however, 'Variety' has also been equally effective ; for the two varieties under observation, *Tilakkachari* > *Latisal*.

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A NEW SIMPLE METHOD OF ESTIMATING THE MOISTURE CONTENT OF SOIL *IN SITU*

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(With four text-figures)

AN accurate estimation of soil moisture is of great importance in agricultural practice as well as in many problems of soil physics. There are serveral methods which at present are in general use for this purpose; but almost all of them are either laborious and slow or are not sufficiently reliable. The method most commonly used consists in taking a sample of soil from the field and driving out the moisture in a steam oven. The loss of weight during the drying process gives the weight of the moisture content which is expressed as a percentage of the weight of the dry soil. This method although fairly accurate is laborious and very slow, as it takes several days to drive out the moisture completely from the soil sample. Various other methods have been tried for estimating the soil moisture more quickly. These may generally be classified as follows:

(i) *Electrical conductivity method.* This method first tried by Whitney, Milton, Gardner and Briggs [1897] uses the electrical conductivity of the soil as an index of soil moisture. The salt content of the soil, however, introduces a considerable error in this method. A modification of the above method using multiple electrodes has been attempted by McCorkle [1931], but the results are reported not to have proved entirely satisfactory.

(ii) *The Dielectric Constant method.* In this method, due to Fletcher [1939], the soil forms the dielectric of a special condenser buried in the ground and the dielectric constant of the soil which varies with the moisture content is taken as an index of soil moisture. Readings by this method are, however, affected by salt concentration and the colloid content of the soil.

(iii) *Tensiometers.* These instruments measure the capillary tension of the soil water. Richards, Russell and Neal [1937], and Richards and Gardner [1936] have investigated the relationship between the water content of soil and its capillary tension. The basic form of this instrument consists of a porous candle filled with water and connected to a mercury manometer. The porous candle is placed in the soil and water moves into or out of the candle depending upon the moisture content (capillary tension) of the soil surrounding the porous candle. This movement of water is indicated by the change in the mercury level in the manometer. The method, however, has proved more useful for the purpose of studying the movement of water in soil than for the determination of its moisture content. This is mainly due to the fact that the instrument requires some time to get into equilibrium with the surrounding soil and hence there is a considerable hysteresis effect in the instrument. It cannot also be used for soil moisture contents below the moisture equivalent, when the capillary tension of the soil-water exceeds one atmosphere and the instrument suffers from the formation of air bubbles which effectively stop the instrument from functioning.

(iv) *Thermal conductivity method.* The variation of heat conductivity of soil with changing moisture content has been reported as early as in 1909 by Patten. It is only recently [1939], however, that a practical method has been proposed by Shaw, Byron and Baver in America utilizing this variation in thermal conductivity as an index of soil moisture. In this method used by Shaw, Byron and Baver the thermal conductivity of the soil is measured with an electrical apparatus based on the Wheatstone bridge principle. An enamelled copper-wire element forming one of the arms of a Wheatstone bridge is buried in the soil and a fixed current (0·4 amperes) is passed through the circuit for one minute. The temperature attained by the copper-wire element at the end of one minute will depend on the thermal conductivity of the soil which in turn will depend on the moisture content, packing and composition of the soil. As the electrical resistance of the copper wire depends on its temperature, the temperature attained by the element at the end of one minute is indicated by the

out-of-balance current in the bridge detector which is a sensitive micro-ammeter. The lower the thermal conductivity of the soil the higher is the temperature attained by this element.

It will be seen that the equipment required for the above method is rather elaborate and requires a sensitive micro-ammeter and a source of constant voltage for the bridge and it is obviously beyond the means of an average Indian farm observatory. The present paper describes a new method based on the same principle but greatly simplified.

The new method and apparatus

In the method of Byron, Shaw and Baver the Wheatstone bridge is used for the measurement of the temperature attained by the copper-wire element at the end of one minute. In the method developed by the present writer, this indirect method of temperature measurement is eliminated by making use of the special type of thermometer which is generally used for the measurement of soil temperature at different depths. These thermometers have very long stems so that when the bulb of the instrument is buried in the ground the scale is above the ground surface. Instruments of this type are available for use at different depths up to 2 ft. below ground level.

On the bulb of such a thermometer is wound a heating element consisting of a No. 32 or 30 enamelled or silk covered constant wire, which covers half the bulb of the thermometer. A coating of an insulating material (Durofix was used in the present investigation) is applied over the wire covered portion of the thermometer bulb. This insulates the heating element electrically and, to some extent, thermally from the soil in which the thermometer is placed and also protects the element from moisture. A 6-volt storage battery or a large capacity dry cell battery is used as the source of heating current and is connected to the heating element through a variable resistance, an ammeter and a switch in series. The bulb of the thermometer is then burid in the ground at the desired depth and in good thermal contact with the soil. The measurement is made by passing a fixed current (0·3 amperes was used in the present investigation) through the instrument and recording the time required to raise the temperature of the thermometer bulb by 5°C. The time is recorded in seconds with an ordinary watch or preferably with a stop watch.

Patten [1909] has investigated the thermal conductivity and diffusivity in soils in relation to their moisture content and other factors, viz. packing, composition, etc. He finds that, the packing of the soil remaining the same, its thermal conductivity increases with its moisture content. Now, the thermometer bulb in the above instrument is heated by a fixed current, (therefore at a constant rate) and, as it is the bare half of the thermometer bulb that mainly dissipates heat through the soil, it will be seen that the time required to raise the temperature of the bulb by a fixed amount will vary with the thermal conductivity of the soil. That is, the packing of the soil remaining the same, it will take longer to raise the temperature of the thermometer by the same amount in a wet soil than in a dry one. This is the basic principle of the instrument. Fig. 1 gives a sketch of the instrument.

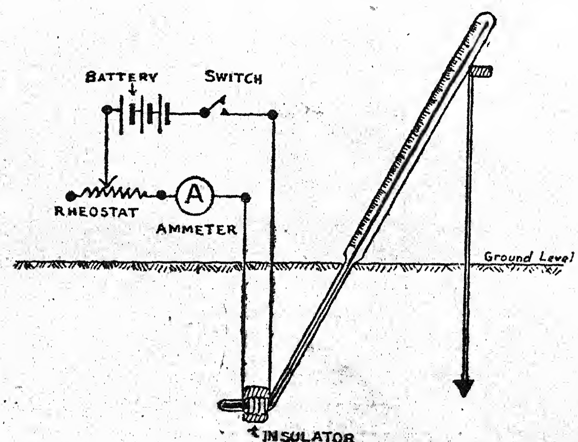

Fig. 1. A sketch of the instrument

The instrument was first tried in the laboratory with Poona Black Cotton soil at different moisture contents. It was, however, not possible to keep the packing of the soil exactly the same at the various moisture contents, but as far as possible, care was taken to see that the soil occupied almost the same volume at each moisture content. After the current was switched on, the readings of the thermometers were taken at intervals of 10 seconds until the temperature increased by 23°C. The results of this experiment are given in Fig. 2. These curves show the effect of moisture content on the thermal conductivity of the Poona Black Cotton soil.

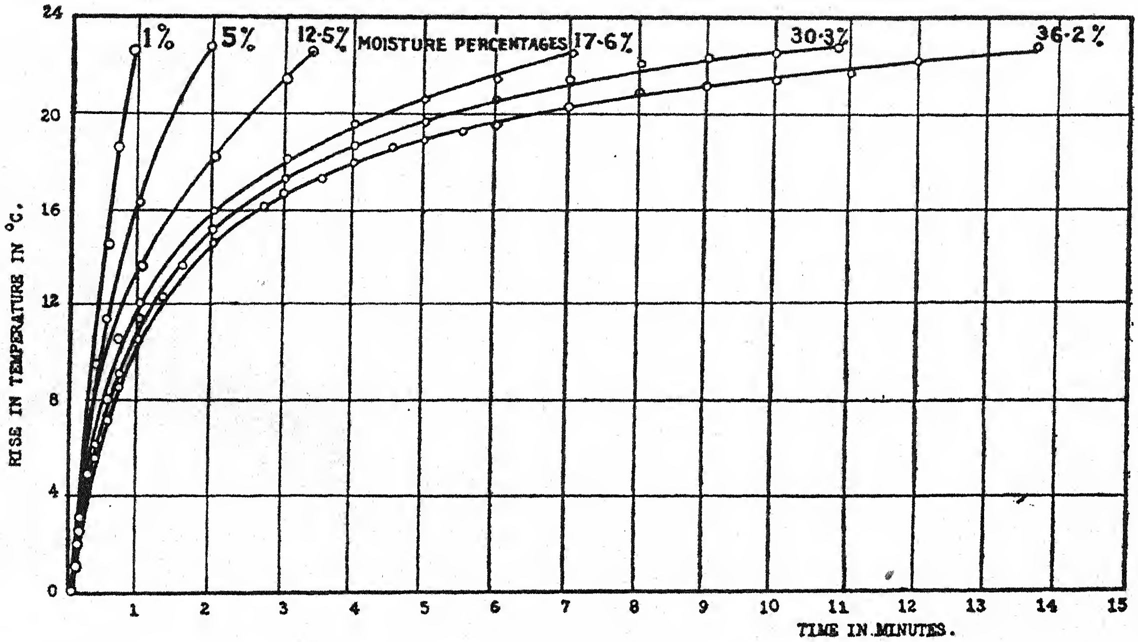

FIG. 2. Temperature—Time curves for Poona Black Cotton soil at various moisture contents with a heating current of 0·7 amperes

The effect of various values of currents has also been studied. Fig. 3 shows the Temperature Time curves for dry Poona Black Cotton soil with different heating currents. It was found that the most suitable value of the heating current depends on

(i) the resistance of the heating element,
(ii) the size of the thermometer bulb, and
(iii) the amount by which the temperature of the thermometer is to be raised.

It is undesirable to use a very high value of current as this will not only reduce the life of the heating element but also will necessitate the use of a large capacity battery. At the same time, it must be remembered that a very low current will reduce the rate of temperature rise of the thermometer and consequently reduce the accuracy with which the time for a definite rise of temperature can be recorded. This is also true of a very high current which will make the rise of temperature too fast for accurate measurement. The current, therefore, should be of such a strength that the rise of temperature should be just fast enough for accurate measurement, when the soil is saturated.

Two instruments of the above type were installed at the Central Agricultural Meteorological Observatory, Poona, at depths of 3 in. and 9 in. below ground surface. A single battery and rheostat were used for both the instruments with a suitable switching arrangement. While installing the instruments, special care was taken that the soil was disturbed as little as possible and that the bulbs of the thermometers were making a good thermal contact with the soil. The readings of the instruments were taken at intervals usually of 3 to 4 days and simultaneously samples of soil were taken

from an adjoining plot from depths at which the instruments were installed. The moisture contents of these samples were determined by the conventional drying and weighing method. The values of

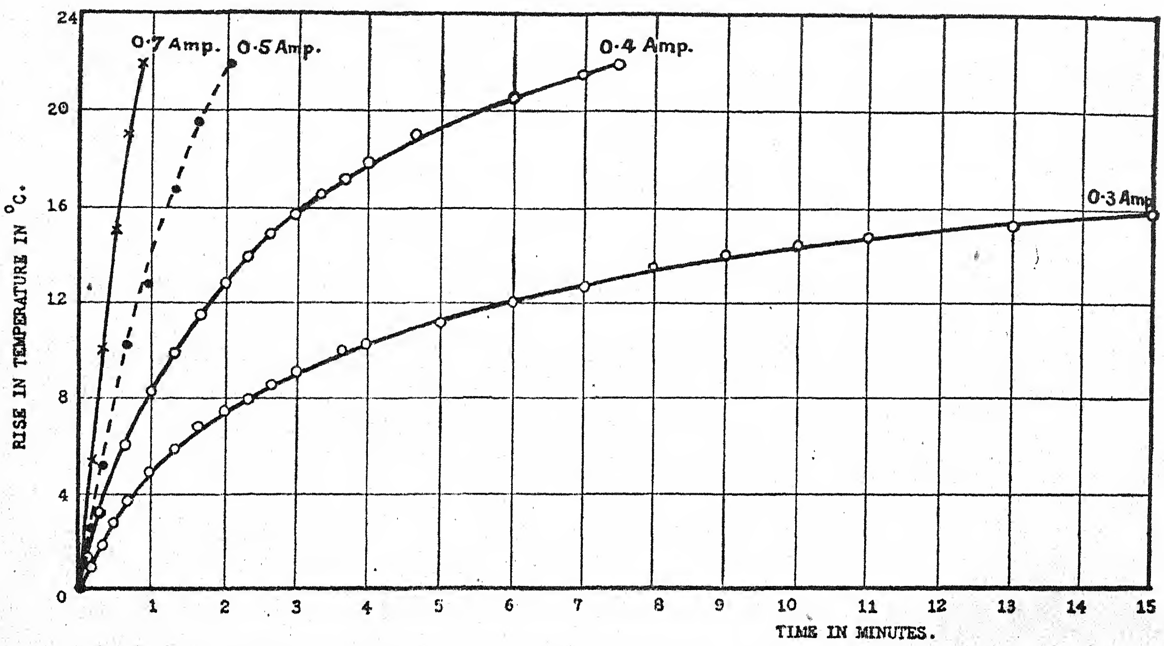

FIG. 3. Temperature—Time curves for dry Poona Black Cotton soil with various heating currents

moisture content thus obtained were plotted against the time 't' in seconds required to raise the temperature of the thermometer by 5°C. Fig. 4 shows the relationship between 't' and moisture percentage for each of the instruments. It is satisfactory to note that almost smooth lines can be fitted through the various points. Whatever scattering of the points is present, is mainly due to errors in judging the exact depth from which the soil samples are taken. This error is especially noticeable in the clear season when the surface layer of the ground has become dry and the moisture content of the soil increases very rapidly with depth.

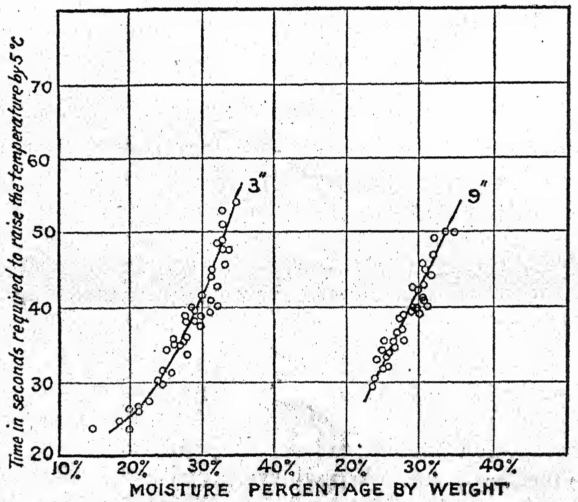

FIG. 4. The relation between 't' and moisture percentage

The regression equations given the relationship between '*t*' (time required to raise the temperature of the thermometer by 5°C. with a current of 0·3 amperes) and '*M*' the moisture percentage of the soil for both the instruments are given below:

3 in. depth—$M = \cdot 86 + \cdot 93t - \cdot 0055t^2$.
9 in. depth—$M = \cdot 51t + 8 \cdot 89$.

Once these curves are obtained for each instrument over the normal range of moisture variations under field conditions, the calibration of the instrument is complete. Later, whenever, a determination of the moisture content of the soil is required, it is only necessary to take a reading of the instrument and read off the value of the moisture content immediately from the corresponding calibration curve. The calibration of the instrument takes, if the right season is chosen (the beginning or the end of the rainy season), about 2 or 3 months.

The only major precautions to be taken while using these instruments are

(i) the instrument as well as the soil around its bulb should not be disturbed in any way, and
(ii) a constant current should be used for taking the time readings.

The first is achieved by keeping a separate plot of ground for the instrument, which is not likely to be disturbed; the second is achieved by keeping the battery properly charged or by making periodical adjustments of the rheostat in case a dry cell battery is used. This does not present much difficulty as the current drain from the battery is only 0·3 amperes and the battery is used only for a few minutes once or twice a week.

The main drawbacks of this method are that variations in the packing of the soil particles effect the readings and that it takes rather long to calibrate the instrument, which must be done on the spot where the instrument is installed. But the same limitations would apply to the method of Byron, Shaw and Baver mentioned above. It may be mentioned here that the variations in the packing of the soil particles, which are due to variations of moisture content of the soil itself do not effect the accuracy of this method, as they are taken into account in the process of calibration of the instruments.

Summary

(i) The method described above is an extremely simple one and is especially suitable for experimental farms in India which usually possess thermometers for recording soil temperatures at different depths. By adding a heating element these can easily be adapted for soil moisture measurements without affecting their efficiency as soil thermometers.

(ii) In addition to the great saving in labour and time by the use of this method it may be mentioned that the accuracy of this method is comparable to that of the drying and weighing method. Further work is in progress.

Acknowledgement

In conclusion the writer wishes to thank Dr L. A. Ramdas, Agricultural Meteorologist, under whose guidance this work is progressing. The writer's thanks are also due to Messrs. Dasradha Rama Rao and V. K. Ramabhadran for computing the regression equations given in the paper.

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METHODS AND FACTORS THAT ENABLE A PLANT TO WITHSTAND TRANSPLANTING

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TRANSPLANTING is a three-act operation. It includes digging of a seedling from its growing place, transporting it to a desired place, and planting it there properly so that it may grow efficiently and effectively. Transplanting--though in itself not an essential operation as will be explained later--is of great economic importance and potentiality in modern agriculture. Man has used it as a great and effective weapon in his continuous effort to overcome the limitations nature has imposed upon him in his efforts to grow his food. By transplanting methods, man has overcome the limitations of a short growing season. He has widened his domain for growing his food into areas which ordinarily would not grow some of the produce because of short growing seasons for them. The economic importance of transplanting, therefore, is so great that study to find the factors and methods for successful transplanting is very essential.

The advantages of transplanting centre around the economic factors. Of course, it helps the man to extend his growing season, and also to have plants where he wants them to be. It helps growers to use most economically and effectively the most valuable space in the greenhouse. A grower can take care of his seedlings in flats in the greenhouse in their early stage, more economically and efficiently. He can do so with less labour, with little fertilizer, and he can protect them more fully from diseases and insects while the seedlings are in the greenhouse. It also makes it possible for the grower to save his seed, and so lower the seed cost considerably. During the operation of transplanting, the unavoidable root injury—in fact, a sort of root pruning—stimulates root growth later, and this branching of roots not only helps the plant to set easily and readily, but also helps it to overcome the transplanting shock quickly.

Transplanting, as suggested above, has in itself no advantages. In fact, it has several disadvantages. It calls for extra labour and extra expenses. The injury to roots is unavoidable, and most of the root hairs are destroyed. The skill and technique can be devised and followed that this root loss could be greatly reduced. Above all, transplanting checks growth. This also retards development, and defers fruit production, so reducing early yield, by the reduction of roots and leaves. The check in growth caused [Loomis, 1925] by transplanting alone, is proportional to the duration and extent of the disturbance of root and top balance, which is a balance between the absorption of water by roots, and loss of water vapour through the leaves and stem. Measures and methods can be adopted which can minimize these disadvantageous effects of transplanting, and so it can well contribute to the success of transplanting. To do so, a study into the nature of problems involved in transplanting is very essential.

Plants vary greatly in their ability to be transplanted successfully. Some plants recover more readily from transplanting than others do. Cabbage, beets, and lettuce are some of those that can be easily transplanted. The check in growth in the case of corn, cucumbers, melons, and beans [Thompson, 1939] is so marked and great that unless the plants are very small, they can not be very successfully transplanted. It has further been found [Loomis, 1925] that plants which are readily transplanted are those whose damaged and destroyed roots are speedily replaced by new root growth. This replacement in turn depends upon the ability of the roots retained by the plant to absorb moisture freely, and this further depends upon the fact that these plants have very little, if any, suberin or corky covering on the roots. Those which are hard to transplant are distinctly suberized.

This should suggest that if speedy root growth somehow can be stimulated and increased, and suberization can be either checked or reduced, the possibility of successful transplanting can be greatly increased. The effect of transplanting shock caused by the disturbance in absorption and transpiration balance could also be minimized if somehow transpiration could be reduced, and absorption could be stimulated and increased. As the absorption of water by roots in general

depends upon the absorbing root area, so care and precaution could be devised to cut down the loss of root absorbing area. The control of temperature, humidity while the seedlings are being transported, and the check in transpiration by some waxy spray, or by any other means, would greatly increase the chances for successful transplanting.

As various factors, both environmental and internal which affect recovery from transplanting, all act through their final effect on water supply, so the solution of the problem of having a water supply in the plant, which supply can be held against unavailability, and which can afford a continuous water supply around the roots after setting transplants, will greatly contribute to successful transplanting. The check in growth, which generally varies directly with the quantity and duration of the reduction of water supply, can so be reduced to its minimum.

The check in growth during transplanting also varies directly in proportion to the size of the plant at the time of transplanting. This difficulty can be overcome by managing to have seedlings of proper size and age, at the proper time, and at optimum conditions. The growth of tender, leggy and older plants will be greatly checked by transplanting, while a hardened, normal size, and healthy plant may come out of the transplanting process with the least check in growth.

Seedlings grown in greenhouses, generally under favourable optimum conditions, usually become rather soft, so at the time of transplanting they will find it hard to withstand the hardship of extremes of weather in the new environments. They become more susceptible to injury from cold and hot weather, from wind, and insects. The loss of water would greatly injure such seedlings, and their immunity towards diseases at this stage could be anything but optimum. Therefore, these plants must be hardened.

For successful transplanting, hardening is one of the most important practices, knowledge of which is very important, for it involves one of the most delicate physiological processes and changes in a plant. Plants are hardened to withstand cold as well as heat. Properly hardened plants can withstand effectively desiccation by dry hot winds, as well as by frost. They can withstand whipping. Hardening of the tissue, and formation of cutin on the leaf surface, and other physiological changes are brought about during hardening. They make the plant less susceptible to the attacks of diseases and insects. They also have less physical injury from handling during transplanting.

Hardened plants are more capable of retaining water. They also accumulate a deposit of carbohydrates during the hardening time. These factors in proper combination are more influential in initiating a prompt regeneration of root growth. This, of course, brings about intensive metabolic activities on the part of the root cell, and this increases respiration, accompanied by a higher rate of transpiration. But the increase in water loss thereby is so insignificant, although unavoidable, that it should be overlooked.

Proper hardening is essential for best results. Gradual hardening gives best results, and also helps to avoid overhardening. To keep plants on the dry side is better, as well as an easy method of hardening plants. It is easy to control moisture by withholding irrigation or by a limited application of water. It involves no extra labour operation, and serves to reduce water and labour costs.

Lowering the temperature is another method practised either alone or along with moisture control to harden plants. It is rather difficult to control temperature, and this involves extra labour and care. Unless great precautions are taken, plants might be seriously injured, or a serious check in growth may occur by too low a temperature. Besides, in the case of certain plants, subjection to cold temperature in early stages would greatly increase the danger of bolting. Cabbage, celery, and beets in particular, are very susceptible to such temperature changes. They, if subjected to cold temperatures for about a week, will mostly go prematurely to seed.

Plants can be hardened also by withholding nutrients. This is a starving method. It is not a very desirable practice, for the starved plants later do not do so well. Yellowing of leaves and stem and toughening of tissue is a very characteristic sign of nitrogen deficiency, quite apart from that caused by cold and moisture deficiency. Starved plants are very slow in overcoming a transplanting shock. They are slow to recover. The yield, especially the early yield, is greatly reduced [Crist, 1928].

All plants cannot be hardened. Tender plants such as potato and sweet potato cannot be hardened. Only hardy or semi-hardy plants such as cabbage, cauliflower, celery, beets, and lettuce, the plants usually so treated, can be hardened successfully.

To understand the nature of hardening, a knowledge of the changes that accompany hardening is very useful and necessary. Rosa [1921] sums up these changes as follows: slowing of the rate of growth; thickening of cuticle and increase in the waxy covering on the leaves; increase in the percentage of dry matter; decrease in the transpiration per unit area of leaf; increase in the quantity of hydrophyllic colloids, especially pentosans; decrease in the freezable or free water; increase in the percentage of total sugar; decrease in starch, and the development of a rather pink red colour, especially in stem, petiole, and leaf veins. The leaves of well-hardened plants are darker green and smaller than those of non-hardened plants of the same age. Hardening brings such changes in proteins as prevent them from precipitating easily. In case of cabbage, increase in amino acids was noticed.

The effect of hardening to establish a morphological trend in the stem is very noticeable especially in hardened tomato plants. This is characterized by an excessive differentiation and maturation of the tissue. This trend [Crist, 1928] involved the leaves and fruits and amounted to a permanent check in general development. The upper part of the plant, which developed subsequent to the period of hardening, had a different morphological trend, and was not affected adversely. The early, but not the total, yield of hardened tomatoes, is greatly diminished. Holding out tomatoes, therefore, is not a very advantageous practice.

The application of nutrient salts previous to setting seedlings in beds [Crist, 1928] did not relieve the check suffered during the hardening process, even though the conductive systen was not impaired, as generally it is not. In the case of cabbage, there was no check in growth of any practical consequence during the temporary limitation of nutrients. So no bad effect may be expected to follow hardening incident to delay in transplanting. This is true also of tomatoes, but with the exception that the hardened part is not rejuvenated. The hardened part is permanently affected, and is characterized by accelerated and increased differentiation and lignification of tissues, which consequently cause reduction in mass of stem and fruit. The growth of the conductive system is, however, not inhibited.

This all brings out the suggestion that on one side, the dependence upon hardened plants is not a desirable practice because preparing tomato plants to survive the rigour of a pre-season environments, imposes a handicap from which they recover so slowly that tender plants set in the field considerably later overtake and surpass them and prove profitable; on the other hand the time of transplanting in the field must be properly calculated, for any plant can stand a certain definite amount of adverse weather and no more.

To have a healthy, properly hardened plant of a certain age and size, a definite plan should be made in early winter, or still better, in fall. To grow your own seedlings or to buy them is an individual problem, but one which must be settled early. If it is decided to grow your own seedlings, the seed of a desired variety, preferably a certified seed of disease-resistant variety, should be had early. Temporary sash-houses, hot beds, hot-bed-pits, or manure heated beds could be arranged. In greenhouses, proper sized flats are very handy. The date of planting seed depends upon the variety, the time it generally takes to grow a good sized seedling, and the approximate time at which the seedlings are expected to be set in the field.

The disease-free flats and soil should be used, and seed should be treated against diseases. In flats, sterile sand is generally used, so that at pulling time, the root injury may be greatly reduced. The seed bed is well prepared and the seed planted in rows and watered well with water at first and later a properly prepared starter solution to keep the soil moist. If need be, the bed should be covered. Great care should be given to the temperature, moisture, and ventilation. Chilling the plants and overheating should be avoided. Soft plants over watered and lacking ventilation become very susceptible to 'damping off'. To protect seedlings from 'damping off,' and to grow them well, the use of *Sphagnum* moss is very effective and so will be discussed later fully. The use of hydrophyllic colloids of high viscosity, such as methylcellulose, as a seedling growing medium has great potentialities as a protection against 'damping off', root injury, and wilting. A protection

against wilting is a direct measure of successful transplanting. The use of methylcellulose in flat soil, or even in the field, seems to be the answer. To be [Felber, 1944] effective in spring, the treatment should be given in fall. Methylcellulose fibres in soil help to conserve the moisture. Proper choice of the amount of methylcellulose and its viscosity grade, giving due regard to the water-holding capacity of the soil and the prevailing condition of moisture and temperature, the method of methylcellulose soil treatment may possibly be successfully used in orchard and fields. It is inverse to sol-gel transformation of agar and gelatin, a fact which is of great advantage for it to be used as a seedling-growing medium, for it will gel in warm weather, but it acts as a sol at cool temperatures, at transplanting time, and thus will keep the root moist, an optimum condition for new root growth. Methylcellulose used in flat soil will not only make it possible to pull seedlings with the least root injury to them, but also will, when around roots, protect them against drying [Felber and Gardener, 1945]. In culture solutions, methylcellulose decreased the water requirement by about 30 per cent. In rich soil, rich in organic matter, the treatment may cause a slight retardation of growth when the moisture content is high. In sandy soil, however, the growth accelerates. So it can be used advantageously to prevent a detrimental effect of a temporary drought period in delaying growth during transplanting. Its use will further cut down the labour requirements and expenses of artificial methods used to avoid wilting. Its use will help to control erosion and prevent run-off water from sandy soil.

Sphagnum moss has been used as a seedling medium. Its use is a very effective control against 'damping off'. Roots of seedlings are least injured at pulling time. It can be easily blocked or balled over roots before lifting, and thus can give a greater protection to roots. It can be easily obtained. The application of nitrate solution or complete nutrient solution is essential, however, especially after transplanting in the field when *Sphagnum* moss is used [Stoxtemyer, 1943].

Seedlings, when growing thick in transplants and having two of their real leaves grown fully, are generally transplanted into other beds of flats with a greater space to each plant, or they are transplanted into pots, dirt bands, paper boxes, paper bands, wood pots, or veneer bands. With a container to each seedling, it becomes easier to handle and transport the plants, but it becomes so expensive. However, it gives best results. Loomis [1925] in New York, found a 30 per cent gain in seedling transplanted in paper boxes over those directly transplanted into the field without being transplanted into any container. It is a great gain, sufficient to meet the extra expenses of containers and handling them.

The container should be sanitary, and they should be soaked in a fertilizer solution before they are used. Wood or paper material around roots causes a condition that brings about nitrogen deficiency, so the use of extra nitrogen is advisable.

Fertilizers, not only in starter solutions for seedlings, but also in the field, are very essential for successful transplanting ; so is the preparation of soil. Properly cultivated soil, loose and friable, moist and retentive of moisture, with sufficient amounts of organic matter, will make successful transplanting much easier. The use of methylcellulose to increase the moisture retentive qualities of the soil, as mentioned above, could be very beneficial. Proper fertilization also is very essential. The actual amount and quality of fertilizer depends upon the initial fertility of the soil. The relative ratio of potassium, phosphoric acid, and nitrogen can be so manipulated that to start with the application of a fertilizer should encourage root growth rather than top growth. The fertilizer with more potassium and a little nitrogen, either in starter solution, or on the planting line in beds before transplanting properly applied could do the trick. Later application of an extra nitrogen solution as a side dressing after the seedlings have set, would prove greatly beneficial in stimulating the top growth.

The soil should be free of weeds, and care should be taken against insects and diseases. Well-drained soil is necessary.

Before the seedlings are brought to the field, they should be well hardened as described above. They can be given several physical as well as chemical treatments to enable them to withstand transplanting better, which will be discussed below. They should be properly pulled with the least injury to roots. It would be better to lift them up with soil and roots from below with a scraper with the least disturbance to the latter. The soil will also protect the roots from drying while being transported to the field. The use of containers, blocking, and 'pricked' plants is a great help in protecting

plants from drying. Plants should be shaded, covered with wet sacking, and the roots should be kept moist. Placing the containers and flats on a flat wagon floor and transporting them to the field would give the least disturbance to the roots, and so the least root injury. Small and weak plants should be discarded.

If the seedlings have to be bought, not only should they be of the proper size and age, but they should be in an optimum condition, and must be had at a desired time. Handling of seedling and packing is very important. They should be bunched and tied with the roots well protected. They should be placed in baskets or special crates, and should be well ventilated. The use of packages, such as are used for vegetables, has a great scope. Parchment or whole hide packages, used for vegetables, can also be beneficially used for seedling transportation. This material can stand water. Properly used at a right temperature in transportation, they may reduce transpiration greatly, and prevent wilting. They permit the air to pass slightly [Brown, 1928], which keeps respiration going, but which does not increase the water loss, by transpiration greatly. Whale-hide excludes light, but parchment permits light to pass through, and so this may even permit the photosynthesis to go on in the packages. Although there is no experimental work to support the suggestions, if such packages are used and photosynthesis can take place in the package, the seedlings could use the carbon dioxide in the package produced by respiration of the plants, and thus could avoid toxication or break down effect of suboxidation in the tissues of seedlings. It could also at least stabilize the carbohydrate supply in the plants, which later may greatly help the stimulation of the new root growth. Packages of celoglass, vitres, flexglass, waxed paper could be used for experimental work. This work could find out which material would suit better. These all with the exception of whale-hide permit the passage of light.

Pliofilm [Stahl and Vaughn, 1942], a nitrogen synthetic plastic, may turn out to be of great use for packages for seedlings. It is a moisture-proof substance, but permits the diffusion of carbon dioxide. The disease side of the problem should be studied and if no danger is found, the use of a little water around the roots in packages can be a great guarantee against root drying.

Not only the study into the practicability of the use of such material for transportation of seedlings would help to find a way of transporting seedlings with the least risk of drying but the study of the use of several waxy or oily materials to be used as a spray on seedlings to check transpiration temporarily would also help a great deal. Pliofilm may prove of great value in this respect too. It will not permit moisture to escape, and will permit diffusion of carbon dioxide. It may do away with transpiration, an unavoidable but necessary evil to plants.

Time and weather conditions also help greatly in successful transplanting. Early in the morning or late in the afternoon, in early spring or late fall in a windless, calm day, or when it is cloudy, or the temperature is low and humidity high, the transpiration is low and there is less chance of wilting, and so a greater time is available for the roots to grow and start working before wilting can take place. Planting in furrows will help against wind.

A hole of proper dimensions for the roots, and a stem set a little lower than its previous level would help successful transplanting. A firm and gentle pressing of dirt on roots to avoid air pockets is of great help. Watering before the hole is closed is of great benefit. Direct water to roots at the time of transplanting [Nuckols, 1931] greatly increases the chances of survival and also increases the yield considerably. It is expensive, of course. A substitute for this method, yet not so expensive, is puddling of seedling roots in a watery mud. The use of special fertilizer, hormone, growth promoting substances, and methylcellulose in this mud may prove of great benefit. A precaution should be taken, however, against letting this mud dry on roots before they are set in the field. The soil around the roots in the hole should be moist, too. The starter solution of KNO_3 and $(NH_4)_2SO_4$ or potassium and phosphoric acid used in a suitable combination as the conditions warrant, in mud, may be of great help in successful transplanting. Putting dry dirt around the stem near the surface is advisable. Sawdust can be used for mulching around the stem near the surface with great benefit, but it may cause a nitrogen deficiency which can be overcome by the application of extra nitrogen solution.

Protecting the transplants from bright sunlight and wind is recommended when economically possible, especially for the first couple of days after transplanting.

Pruning of top and roots is practised sometimes. 'Snipping off,' pinching, or even defoliation is practised with the idea of cutting down transpiration. Pruning of damaged and injured roots may be advisable to give a stimulation to root growth, but generally root pruning should be avoided. Pruning of top and roots has been found to decrease the yield [Krause, 1944]. Defoliation or pruning the top may reduce the transpiration and thus facilitate successful trasplanting, but it would also cut down the production of carbohydrates which are much needed for new root growth. It will delay the crop, and may reduce the yield considerable. Pruning of top and roots, however, is practised on celery without too much set back. 'Snipping off' the upper part of the cabbage plant may be practised advantageously when dry weather is a serious factor, and if the growing season is long, for the crop will be late. Pinching back of the main stem of tomatoes will make the fruit setting late, but those of the lateral shoots of a stacked tomato plant would increase the early yield. Defoliation of lettuce plant [Krause, 1944] reduced yield and delayed maturity of head lettuce. The same result was obtained with cauliflower. Even in case of celery, heavily pruned plants yielded less than unpruned plants. Pruning, however, did not effect the length of the petiole. Pruning of celery plants below their eight week limit did not prove to be of any harm, and unpruned onions did not show any advantage over pruned onions.

As far as transpiration is concerned, unpruned plants transpired less per unit area than pruned plants.¶ In general, the rate and amount of root and top growth of cauliflower and celery plants subsequent to pruning were reduced in proportion to the amount of foliage removed. Plant recovery and resumption of root and top growth after transplanting appeared to be directly correlated with the amount of carbohydrate present in the plant after pruning or at the time of transplanting.

The presence of carbohydrate, especially in relation to nitrogen in plants, is another angle, study of which may help greatly in successful transplanting, for it has been found that the relationship of carbohydrates to nitrogen in plants influences a great deal the top and root growth. Although most of the work has been done on fruit twigs, which work is briefly reviewed here with the notion that similar work on vegetables may give similar results.

Goldlewski's [Reid, 1924] work suggests that in the absence of nitrogen, root formation is favoured more than shoot formation. Chandler [1919] found that root growth increased much less than top growth by the addition of nitrates to peaches. Gericke [1922] has found that an abnormally large root development of wheat seedlings in proportion to that of top is primarily associated with deficiency of nitrogen in the subsequent substrate. Dachnowski [1914] working on tomato cuttings, found that cane sugar solution somewhat increased root growth. The knowledge of this fact can be exploited by dipping seedling roots in a proper cane sugar solution before transplanting, or even when they are growing in the flats. The work of Knudson [1916] supports the above view for he found a marked influence of certain sugars on root growth of seedlings in relation to both their extent and their branching. Krause and Kraybil [1918] observed that a decided reduction in the development of root systems of tomato plants accompanied a continued removal of leaves from the top. According to micro-chemical tests, the practice also resulted in a marked decrease in carbohydrates in the stem and decided reduction in vegetative extension.

After the short review of carbohydrate and nitrogen relationships as to root and top growth, we can better appreciate why the defoliation practice in transplanting time is more harmful than beneficial, and also why hardening, besides its other advantages, helps greatly in successful planting by the accumulation of carbohydrates.

The interrelation of material within and without the plant is of great influence on top and root growth. Robbins [1922] found that excised roots of several kinds of seedling would, under sterile conditions, develop a considerable root system in a mineral nutrient solution containing carbohydrate, but that little growth in one to which no nitrate was added. The root would not continue to grow indefinitely under either of these conditions. His conclusion is that the root of a seedling derives some material from the seed other than glucose, the mineral salt, water, oxygen, which are necessary for continued growth and which new roots cannot synthesize in the dark in solution culture from which the materials are supplied.

Turner [1922] suggests that the increase in ratio of top to root, which results from increasing the amount of nitrates in the solution, may be explained on the basis of the increased use of carbohydrates in the top, because the greater nitrogen supply makes for greater growth. This results in decrease in the supply of carbohydrates for the roots, which may bring about an absolute or relative reduction of root growth. This suggestion gives us a clue as to why an application of nitrates at the time of transplanting is not advantageous for then the problem is to have more root growth than top growth.

Reid [1924] substantiates through her work the above results. She found that smaller supplies of carbohydrates were associated with a relatively smaller quantities of roots than shoots. A small supply of nitrogen had a more limiting effect on shoot production than it had on root production. It is the relationship of nitrogen to carbohydrates, not the definite ratio actually, that has an influence on root and top growth. Her work shows that light encourages shoot growth and darkness root growth.

Ellis and Eyster's [1931] work which interests us here is the study of the effect of insulin and glucokinin on maize seedlings of green and non-green type. They found retardation in growth of seedlings grown in distilled water containing per cent of insulin or glucokinin. In the stronger solution, the formation of secondary roots was practically inhibited. In solutions weaker than 0·005 per cent, growth was somewhat increased. This latter concentration of insulin or glucokinin may possibly be exploited for successful corn transplanting, at least on a small scale.

Priestly [1929] did work, which, although on twigs, may suggest another aspect of the use of chemicals in successful transplanting. He found that acids favour the apical organization of the roots, and an alkaline condition, the shoot meristem. Protein leaves the alkaline side rapidly. He found plants in KH_2PO_4, a relatively acid solution, gave buds in three days and roots developed two days later, but when a relatively alkaline solution of K_2HPO_4 was used instead, the roots developed in three days and buds after two weeks. On the basis of these results, he developed a *p*H hypothesis, an understanding and application of which may be greatly exploited for successful transplanting by encouraging root growth.

Some hormones and other growth-promoting substances which can encourage diffusion from one tissue to another of chemical substances which affect permeability, protoplasmic power of synthesis, and cell division, may turn out to be of great help in successful transplanting. Transplantone, a plant hormone, is on the market, a claim for which is made that it reduces wilting and starts growth sooner, without interfering with the proper development and growth of plants. It is being used on trees and shrubs. As to how it would work on vegetables, there is no experimental work to base an opinion upon.

In closing, a little discussion on treatment of plants and cut flowers under water in partial vacuum [Hamner, 1945] may be of great help to understand its significance for successful transplanting. Six inches tall tomato plants under water were subjected to a vacuum of 30 lbs. per square inch for 20 minutes. The coming out of air bubbles from the plant indicated that it is being replaced by water. Plants treated thus were placed at 95° F. and a relative humidity of 20 per cent. The check plants showed wilting after five minutes and after thirty minutes they were badly wilted, while vacuum treated plants showed wilting only after four hours and only half were wilted in seven hours. When these were put into water, most of them recovered, while most of the untreated plants did not recover after they were placed in water.

This vacuum treatment of plants under water is of great significance. Its use on seedlings that are being shipped for long distances especially, would greatly increase their ability to withstand wilting, and so would contribute greatly to the maximum success in their transplanting.

Summary

A successful transplanting is a four-fold problem. First it is a problem of cutting down transpiration below absorption of water by the roots. Second, it is a problem of encouraging prompt regeneration of new root growth. Third, it is a problem of storing water and suitable food material,

both within the plant and around the roots, so that it may not wilt ; instead it may initiate new root growth. Fourth, it anticipates a problem of hardening of the plant to enable it to withstand successfully the rigour of the preseason weather. Any method, measure or factor that helps a plant to face these problems successfully, would contribute greatly to successful transplanting.

Hardening makes a plant, not only able to withstand extreme weather conditions, but also cause an accumulation of carbohydrates, which later contributes to prompt initiation of new root growth. The discovery and subsequent use of some carbohydrates, other chemicals with suitable pH, and the root-growth-promoting harmones, would undoubtedly be a great contribution to successful transplanting.

The proper use of methylcellulose in field soil or in flat dirt could be a great protection against root drying. It can hold considerable moisture and also would permit least injury to roots at the time when plants are pulled for transplanting. It will also help in reducing the danger from ' damping off ', a disease which is very fatal to seedlings.

The knowledge and subsequent use of certain suitable sprays used at the time when plants are pulled for transplanting, could reduce the hazard of wilting. Suitable packages for shipping seedlings, either alone or with the use of a spray, could be used effectively to reduce the danger of root drying and wilting by cutting down the water loss through transpiration. In this respect substances like pliofilm hold great promise.

Partial vacuum treatment of seedlings under water is very effective to enable a plant to delay wilting for several hours. Its use, along with sprays or suitable packages could greatly help the seedling shipping industry. It could also be used locally especially when the wilting danger at transplanting time is great—and this economically too.

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D

VARIETIES OF LUCERNE (*MEDICAGO SATIVA*) FOR CULTIVATION IN THE PUNJAB

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(With two text-figures)

Lucerne is one of the very important fodder crops of this province; no other perennial fodder crop yields such a high tonnage under irrigation as this crop.

Lucerne is the oldest plant cultivated solely for forage. The expansion in the acreage devoted to this crop has been gradual and has tended to keep pace with the expansion in canal irrigation; but this gradual increase in lucerne cultivation does not mean any lack of appreciation of the high value of the crop, and its importance in the farm economy of the Punjab.

Despite the length of time lucerne has been in cultivation, one is sometimes struck by the paucity of varieties actually being grown today. This fact is, however, no indication that this crop has received little attention as regards the introduction of varieties from other countries with a view to improve the existing situation.

A recently concluded international variety trial, which ran for a period of six years at the Fodder Research Station, Sirsa, and which embraced a comparison of our common varieties with varieties from other provinces in India and abroad, showed fairly conclusively that, over a period of years, varieties from abroad do not compare very favourably with the indigenous varieties. In this trial not only the yielding ability of the variety was made an index of its value, but also such characteristics as longevity of the variety and mortality were kept in view. In addition, it was apparent that the exotic varieties had to contend with the aclimatization factor, whereas varieties, obtained from India, had adapted themselves to local conditions over a long period of years, having been subjected to natural selection. The foreign varieties on the whole showed a marked reduction in yield after a period of a few years mainly through the death of plants.

As a result of these conclusions, it would appear that varieties in cultivation in this country provide good material for cultivation. There is, however, a vast scope for the improvement of present day varieties by means of both breeding and selection work. Although a stage has been set for the improvement of the crop by breeding, several years must necessarily elapse before seed of improved lucerne types can be made available to the growers. Until this work is carried out with success, there is a very limited choice available to the growers; and the results of the experiment, carried out at Fodder Research Station, Sirsa, should be of great interest to the lucerne growers.

Material and methods

Seed was procured both from abroad and from various provinces in India. The varieties from the former source included three from South Africa, viz. African Chinese, African Province, and Hairy Peruvian; one from Tashkent (U. S. S. R) and one from Carters (Great Britain). The varieties from Indian provinces included two from the United Provinces and one from the Central Provinces and one from Poona (Bombay). Some of the characters of these 10 varieties have been given in Table I.

With the limited knowledge of each variety, the grower finds difficulty in the selection of the most suitable, in assessing the benefits he is likely to derive from the cultivation of one or the other variety, and in finding out whether the differences in price of seed are justified. Any short term experiment over a period of two or three years only may be quite misleading, especially in regard to longevity. Taking these points into consideration the results of a varietal trial which was continued for a period of six years should be of interest.

TABLE I

The characters of lucerne varieties

Variety No.	Form of sprouting plant	Height	Tillering	At maturity		Leaf		Flower		Pod		Seed
				Colour of stem	Character of stem	Size	Quality	Colour	Size	Colour	Spirol	
4. Chinese (South African).	Erect	Medium 3·36	Medium 69·2	Green	Thin, filled	Small	Great dark green	Light violet	Big	Smooth brown	2¼ screw	Big yellow
6. African Province (South Africa)	Erect	High 3·20	Strong 86·0	With anthocynine	Thick, more or less filled	Long	Great deep green	Carmine violet	Big	Light smoky	1¼ cork screw	Medium yellow
7. Utah (U. S. A.)	Erect	High 3·40	Strong 73·5	With anthocynine	Thick, filled	Very big	Great green	Carmine violet	Big	Light smoky	2 cork screw	Medium yellow
11. Hairy Peruvian (South Africa)	Erect	High 3·34	Strong 73·6	Green	Thick, filled	Medium	Great green	Light violet	Medium	Smoky	2 cork screw	Medium yellow
14. Poona (Bombay)	Erect	High 3·75	Low 53·4	Light green	Medium, more or less filled	Small	Little	Light violet	Medium	Light brown	¼ cork screw	Medium yellow
15. Tashkent 988 (U. S. S. R)	Erect	High 3·36	Medium 79·0	Green	Thin, filled	Medium	Medium	Violet	Medium	Smoky	1½ cork screw	Medium brownish green
U. P. 9	Erect	High 3·2	Strong 57·6	Green	Thick, filled	Big	Great dark green	Light violet	Big	Light smoky	2 cork screw	Yellow
8. (U. P.)	Erect	High 3·10	Strong 98	Green	Thick, filled	Big broad	Great dark green	Carmine violet	Medium	Light smoky	2½ screw	Greenish yellow
21. Neemuch (C.P.)	Erect	High 3·93	Medium 111·1	Green	Thick, more or less filled	Small	Medium deep green	Violet	Big	Brown	2 cork screw	Light brown
23. Carters (London)	Erect	High 3·4	Medium 97	Green	Thick, filled	Big	Great green	Light violet	Medium	Light brown	2½ cork screw	Green brown

The usual method of comparison of yield data from fodder experiments is based strictly on the average yields obtained. While average yields offer the best direct basis of comparison of various plot treatments, they may nevertheless be supplemented with advantage by additional data such as height, tillering capacity, and uniformity of stand. It is possible that the results of the fodder experiments carried out for a period of years may be more interesting when average yields of some of the good varieties are expressed in relation to different environment and seasons as represented by years.

The yield data of the ten lucerne varieties, viz., Nos. 4, 6, 7, 8, 9, 11, 14, 15, 21 and 23 from an experiment conducted at the Fodder Research Station, Sirsa, were available for study. The comparative fodder yield trial was started in 1936-37 and has been carried on up to the end of the year 1942 making the yield data of six year period available.

The test was conducted with these varieties in ten replicated randomized plots, each of which was 1/156th acre in area. The sowing was done by means of a hand drill in rows 1 ft. apart. The germination and stand were very uniform to start with and the crop became ready for first cutting in March 1937, *i.e.* after a period of four months.

Discussion of results

The time and frequency of cutting lucerne are influenced by so many variable factors, such as moisture supply, soil conditions, length of the growing season, intensity and duration of solar radiation, severity of winter seasons, etc., that no cutting schedule could be fixed. The crop was harvested for fodder as soon as the varieties started first flowering. An insect, the leaf hopper (*Empoasca fabae*) had a direct bearing on the time of cutting in the years 1940-41. Leaf hoppers easily cause serious injury, because if the adults lay eggs in the young second growth, severe damage occurs on account of large populations of resulting nymphs. The new crop growth had, therefore, to be cut before it was ready, in order to remove the eggs in the fodder and to reduce infestation of the second growth.

Except the attack of this insect in the years mentioned and the influence of heat combined with humidity during the monsoons, which resulted in numerous casualties in the stand of the crop, no other factor was observed to have caused any retardation in growth. The yields of green fodder obtained during the course of the experiment show clearly how each variety responded to these conditions. The average yields of green fodder obtained from each variety in the six years were analysed according to Fisher's method of analysis of variance, and are given in Table II.

Table II

The yields of green fodder and cuttings of the ten lucerne varieties during the period 1937-42 at the Fodder Research Station, Sirsa

Yield per acre in maunds.

Year	No. of cuttings taken during the year	4	6	7	8	9	11	14	15	21	23	Significance		Remarks
												1 per cent	5 per cent	
1937	6	294	304	331	499	445	232	433	402	328	281	..	6·6	
1938	10	585	757	753	1108	1053	304	113	1006	869	445	9·67	7·03	
1939	8	782	1021	998	1135	1140	421	59	1180	1013	560	13·45	9·98	
1940	11	690	916	893	1040	1119	363	19	1091	870	491	14·16	10·73	
1941	11	530	729	768	889	913	261	8	897	725	473	33·75	25·46	
1942	9	270	423	496	627	656	111	2	589	473	138	30·4	23·1	
Average yield per acre		521	692	707	883	888	282	107	861	713	398			

The yield per acre of green fodder obtained during the year 1942, together with the average yield produced over the whole period of six years of the experiment from 10 varieties, is given in Table III.

TABLE III

Yield of green fodder per acre in maunds

Variety	Average of 6 years 1937-42	1941-42
4	521	270
6	692	423
7	706	496
8	883	627
9	888	656
11	282	111
14	107	22
15	861	589
21	713	473
23	398	138

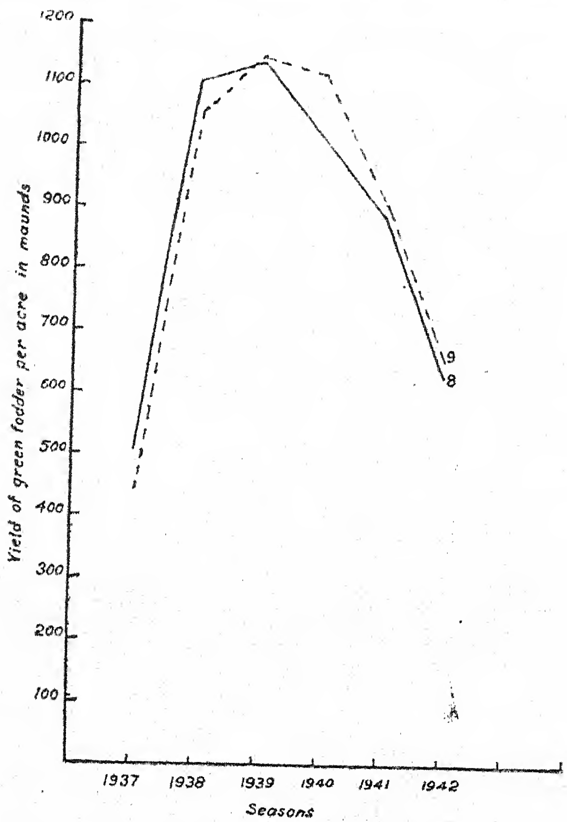

Fig. 1. Average yields of lucerne Nos. 8 and 9 from year to year

Average yields per acre of all the varieties tried and those recommended for cultivation in the Punjab, viz. 8 and 9 are further presented graphically, showing the relative yields from year to year (Fig. 1).

It will be noticed that even after six years the yields remain high in the case of Nos. 8 and 9 and to some extent in Nos. 7 and 15, while that have fallen considerably in all the others. These results support the statement that exotic varieties from abroad, viz. Nos. 4, 6, 11 and 23 do not maintain their yields over a long period of years like the more commonly grown country varieties.

Nos. 8 and 9 showed definite superiority in respect of yield and, in addition, maintained their lead throughout the experiment; No. 15 stood third in total yield and out yielded all varieties in the experiment in 1939. The differences between the total yields of Nos. 8 and 9 were almost negligible as is seen in Fig. 2.

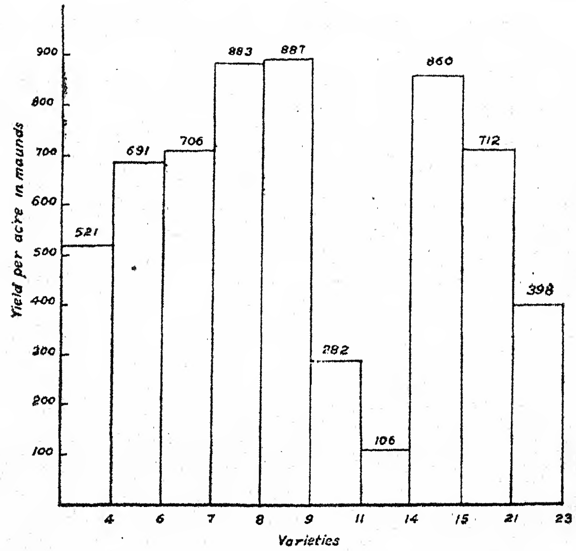

Fig. 2. Average yield of green fodder of 10 lucerne varieties over a period of six years.

These results have been further corroborated by the results of other experiments with some of these varieties at other departmental stations. Table IV gives the yield of green fodder per acre at Montgomery, Hansi and Gurdaspur Agricultural Stations.

TABLE IV

The yield of green fodder per acre in maunds

Year	Station	Local	Varieties					Significance	
			6	8	9	15	21	1 per cent	5 per cent
1939-40 .	Montgomery	207	345	375	363	342	339	18·02	13·37
1940-41 .	Montgomery	425	672	762	692	690	677	18·69	13·88
1941-42 .	Montgomery.	501	715	795	686	743	689	18·44	13·69
1940-41	Hansi	..	..	186	195	157	..	..	..
1941-42	Hansi	..	..	496	518	445	..	..	..
1941-42	Gurdaspur	..	..	394	343				

From an examination of Table II it will also be observed that during the first year Nos. 8, 9, 14 and 15 yielded more than 400 maunds of green fodder per acre, and only small differences were discerned among them; but in the second year of their growth, No. 14 was the poorest yielder. There was, however, insignificant difference among the other three varieties which yielded more than 1,000 maunds in ten cuttings. These three varieties Nos. 8, 9 and 15 maintained their superiority over

others throughout the remaining period of the experiment. But in the sixth year, Nos. 8 and 9 gave comparatively higher yields than No. 15.

Nos. 8 and 9 yielded, on the average of six years 882 and 887 maunds of green fodder per acre respectively. In the sixth year, however, they gave an outturn of 627 and 656 maunds per acre respectively which is higher than all others.

Apart from the yielding abilities of the different varieties, longevity of a variety is a very desirable character and may be influenced by soil conditions, fertility and available moisture, hoeing, and weeding of the crop. However, varieties growing under equal conditions do manifest considerable variation in vigour and ability to last, and this can be seen in Table V which gives the number of total plants of each variety in the year 1940 after a period of four years.

TABLE V

The number of total plants in each variety in the experiment after a period of four years

Variety	No. of total plants in 10 repeats
4	1621
6	1884
7	1998
8	1993
9	3268
11	546
14	26
15	2241
21	1862
23	395

The amount of space covered by each variety during the fourth year as shown by the number of plants varied to a very great extent. Although the amount of ground covered by Nos. 8, 9 and 15 also show great variation, it is the highest in case of No. 9 while low in the case of Nos. 8 and 15. From the figures presented above, it would appear that No. 9 after 6 years had a much better stand of plants than Nos. 8 and 15; No. 8 with a comparatively lower number maintained its yielding ability due to vigorous growth and bigger stools. Other varieties have not only shown poor ability to survive, but in addition there has been marked encroachment by weeds. No. 14, which yielded about equal to these superior varieties in the first year, gave the poorest yields later on, because of the largest number of post germination resulting in plant casualties. These varieties, i.e. Nos. 8, 9 and 15 reached a stage in the sixth year at which it was considered uneconomical to retain them any further.

It has already been mentioned that none of the varieties, viz. 8, 9 and 15 can be identified from their vegetative characters when grown side by side. However, differences in vigour of their growth were notable.

No. 9 is erect and vigorously growing, tillers profusely, with numerous branches. Its leaves are medium sized and dark green in colour, flowers light violet, mature pod light smoky and of medium size with plump kidney shaped seeds light yellow in colour. No. 8 is also an erect and a vigorously growing variety. It tillers profusely and each tiller has several branches. Leaves are broad and dark green in colour, flowers violet, mature pods light smoky and of medium sized with plump, kidney shaped seeds yellowish in colour.

Both have given exceedingly good account of themselves and have been placed on the list of approved seeds of the Agricultural Department, Punjab.

SUMMARY

Until such time as improved strains of lucerne are put on the market, the varieties Nos. 8 and 9 are superior to others under irrigation, and have been recommended for cultivation.

These varieties not only gave high yield of green fodder from the very start, but maintained their high yielding ability for a large number of years.

The high yields are due mostly to their uniformly good stand throughout the period of six years. No. 9 covered the maximum amount of space but No. 8 compensated for it by quick growth and high tillering ability.

In addition to the high fodder yield, ability to survive over a number of years is an important factor determining the selection of a variety. No. 9 was superior to all others in this respect as it had the least number of pest germination resulting in plant casualties, Nos. 8 and 9 both have, therefore, been recommended for cultivation in the Punjab.

A PRELIMINARY NOTE ON THE ESSENTIAL OIL BEARING PLANTS GROWING IN KASHMIR, II

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In a previous paper [Chopra *et al* 1946] we gave the results of investigations carried out in the Drug Research Laboratory in connexion with the essential oil bearing plants growing in Kashmir. In some the yield of the essential oil was too small for commercial exploitation while in others it was promising. This latter group has been taken up for detailed investigations and the results of these studies will be communicated in due course.

Since then a number of other plants with reputed aromatic properties have been collected in course of our botanical excursions in different parts of Kashmir. The results of preliminary investigations on these plants are reported in this paper.

The plants mentioned below have been studied :—

Acorus calamus. (*Sweet flag ; Vern. Bach, Vai*).

This plant is a semi-acquatic perennial herb with an indefinitely branched rhizomes. It is originally a native of Europe and North America but has been cultivated in India in damp marshy places at altitudes of 3,000 to 6,000 ft. above the sea level. In Kashmir it grows on the borders of lakes and marshy areas. The rhizomes are used in the indigenous medicine as emetic, nauseant, antisposmodic and carminative ; they are also used in the treatment of asthma, diarrhœa and dysentery [Chopra, 1933]. In foreign countries the normal oil of sweet flag is used as a perfuming material and also as an ingredient in imparting flavour to gin and some types of beers.

The fresh and unpeeled rhizomes of the plant were steam-distilled and an oil with a brownish yellow colour and agreeable odour was obtained. The properties of this oil were studied and compared with the foreign oil [Glidemiester and Hoffmann, 1922] as given below :—

——	Local oil	Indian oil	Foreign oil
Yield of the oil from unpeeled rhizomes	3·1 per cent	1·5 to 3·5 per cent	1·5 to 3·5 per cent
Specific gravity	1·08 at 15°C.	1·069 at 15°C.	0·959 to 0·97 at 15°C.
Refractive index	1·5475 at 20°C.	....	1·5028 to 1·5078 at 20°C.

Cinnamomum tamala (*Vern. Tejpat, Dalchini*)

Official cinnamon oil is obtained from the bark of *Cinnamomum zeylanicum*, a tree which is indigenous to Ceylon. This oil is carminative and has antiseptic properties and is used in medicine.

Cinnamomum tamala grows wild in the Rajouri and Kathua forests of Jammu province in Kashmir State. The bark possesses a cinnamom-like odour and the leaves are used locally in place of

cinnamon bark. In order to determine if this species of cinnamomum can be exploited for the production of cinnamom oil, both the dry leaves and bark were steam-distilled and a light brown oil was obtained. The properties of this oil were studied and compared with the oil obtained by Schimmel and Co. from the East Indies [Gildemiester and Hoffmann, 1922] as given below :—

——	Local oil	Foreign oil
Yield of the oil from dry bark	0·05 per cent	....
Yield of the oil from dry leaves	1·2 per cent	....
Specific gravity	1·023 at 15°C.	1·0257 at 15° C.
Refractive index	1·5775 at 20°C.	1·52596 at 20°C.

Hyssopus officinalis (*Vern. Zufah-yabis*)

Hyssop oil is mainly distilled from *Hyssopus officinalis* which is indigenous to countries bordering on the Mediterranean sea and also in Central Asia. The plant grows in Baluchistan and in the Himalayas at altitudes ranging from 8,000 to 11,000 ft. It is not indigenous to Kashmir Valley but has been successfully cultivated in the Forest nursery at Baramulla.

The leaves of the plant are used in the indigenous medicine as a stimulant, stomachic, expectorant, diaphoretic and as an emmenagogue [Chopra, 1933]. Hyssop oil is also much esteemed for flavouring purposes and is said to be an ingredient of some of the French liquors [Parry, 1925].

Both the fresh and dry herb procured from the forest nursery were steam distilled and a brownish yellow oil with aromatic odour was obtained. For comparison the properties of the local oil and that of the foreign oil [Gildemiester and Hoffmann, 1922] are given below :

——	Local oil	Foreign oil
Yield of the oil from fresh herb	0·36 per cent	0·07 to 0·29 per cent.
Yield of the oil from dry herb	0·7 per cent	0·3 to 0·9 per cent.
Specific gravity	0·9375 at 15°C.	0·927 to 0·945 at 15°C.
Refractive index	1·4778 at 20°C.	1·473 to 1·486 at 20°C.

It appears from the data given above that the yield of the oil from the herb and the physica constants of the oil compare favourably with those of the foreign oil. The plant has acclimatized well for artificial cultivation in Kashmir Valley and can be commercially and economically exploited.

Angelica glauca (*Vern. Chora*)

This plant grows in abundance in moist places at altitudes of 7,000 to 9,000 ft. and is very common in Kisehnaganga Valley. Locally the root is much used by the inhabitants as a spice ; it is also used in the indigenous medicine in the treatment of dysentery, constipation and as stimulant and cordial tonic. In the foreign countries the Angelica oil obtained from *Archangelica officinalis* is used in perfumery and in flavoring of liquors.

The dry roots of the plant were steam-distilled and a brown yellow oil with the following properties was obtained. The constant of the foreign oil [Gildemiester and Hoffmann, 1922] are also given below for comparison.

——	Local oil	Foreign oil
Yield of the oil	13 per cent.	0·35 to 1 per cent.
Specific gravity	1·0275 at 15°C.	0·859 to 0·918 at 15°C.
Refractive index	1·529 at 20°C.	1·477 to 1·488 at 20°C.

Salvia species

Sage oil which is largely used in foreign countries is obtained from *Salvia officinalis* which is indigenous to the Mediterranean area and is also cultivated in many countries with temperate climate as an ornamental plant and also for its medicinal properties. The oil is largely distilled in Dalmitia and its yield ranges from 1·3 to 2·5 per cent [Parry, 1925].

A number of species of *Salvia* grow wild in the hills bordering on the valley of Kashmir. These are reputed both for their medicinal and aromatic properties. The species which commonly occur here are: *Salvia moorcraftiana* (Vern. *Kalijarri*), *S. glutinosa*, *S. dumitorum*, *S. hians*, *S. latana*, etc. In order to see if these species can be suitably exploited for the production of Sage oil of commerce the first named four species were collected from the Sindh division in Kashmir. The dry leaves and flowering tops were steam-distilled and the following yields of the oils were obtained :

1. *Salvia moorcraftiana*	0·25 per cent
2. *S. glutinosa*	0·32 per cent
3. *S. dumetorum*	0·34 per cent
4. *S. hians*	0·24 per cent

The percentage yield of the oils of these species is so low that no economic exploitation of these can be undertaken. It is, however, possible that the yield of the essential oil may increase on cultivation on suitable soil. This will be tried. The other species are under investigation and their results will be communicated in due course.

Elsholtzia species. Many species of *Elsholtzia* are found growing wild in valley of Kashmir but only two species for the present have been studied for their essential oil contents. These are *E. cristata* and *E. densa*.

Elsholtzia cristata. This plant was used in the indigenous medicine as an antipyretic and diuretic but this has now been given up. It grows wild in Kashmir Valley on the banks of streams. The dry herb was steam distilled and a yellow oil, turning brown on standing, was obtained. The properties of the local oil were studied and compared with the foreign oil [Gildemiester and Hoffmann, 1922] are given below :

—	Local oil	Foreign oil
Yield of the oil	0·93 per cent	2·00 per cent
Specific gravity	1·023 at 15°C.	0·970 at 15°C.
Refractive index	1·529 at 20°C.	—

Elsholtzia densa (*Vern. Poodina*). This is an annual herb found commonly in Sindh division of Kashmir Valley. The whole dried herb was steam distilled and a brownish coloured oil with the following properties was obtained :

Yield of the oil	0·98 per cent
Specific gravity	0·9697 at 15°C.
Refractive index	1·4675 at 20°C.

Heracleum Vcachemiricum

This plant is commonly found wild in the mountain regions in Kashmir especially in the Gurez Valley up to an altitude of 11,000 ft. The fruits and leaves of this plant have aromatic properties.

The dry fruits collected in the month of September were steam distilled and a brownish oil with the following characteristics was obtained :

Yield of the oil	0·8 per cent
Specific gravity	1·0304 at 15°C.
Refractive index	1·504 at 20° C.

Artemisia species

Many species of *Artemisia* are found growing wild in Kashmir Valley and some of them are economically exploited here, e.g. *Artemisia brevifolia*, for the production of santonine. *Artemisia absinthium* which yields the wormwood oil also grows abundantly in Kashmir.

With a view to study the essential oil contents of these species the following plants were collected.

1. *Artemisia dracunculus*
2. *A. laciniata*
3. *A. amygdaliana*
4. *A. grata*
5. *A. parviflora*

Artemisia dracunculus yields the estragon oil of commerce which is largely used in conserves and in the preparation of aromatic vinegar. The flowering shoots of the above plant were steam distilled and a brown oil was obtained. The yield and other properties were determined and compared with the foreign oil [Gildemiester and Hoffmann, 1922].

———	Local oil	Foreign oil
Yield of the oil	0·7 per cent	0·25 to 0·8 per cent
Specific gravity	0·9492 at 15°C.	0·900 to 0·945 at 15°C.
Refractive index	1·5235 at 20°C.	1·502 to 1·514 at 20°C.

The other four species yielded on steam distillation only traces of essential oil; therefore, their other properties could not be studied.

Macrotomia benthami. (Vern. Gaozaban)

The plant grows wild at altitudes of 10,000 ft. and is largely met with in Gurez and Chota Deosai in Kashmir Valley.

Water, *sharbet* and jam prepared from the flowering shoots is extensively used by *hakims* in deseases of tongue and throat and in the treatment of fevers [Kaul, 1928].

The whole of the dry plant was steam distilled but essential oil could only be extracted in traces.

Rhus succeedana (Vern. Arkhar)

This plant commonly grows in the forests of Kashmir and is reputed for its aromatic properties. Both dry fruits and leaves were steam distilled but only traces of the oil were obtained.

Vitex negundo (Vern. Nergundhi) and Lantana camara (Vern. Vhaneri)

These are both extensively used in the indigenous medicine and are reputed for their aromatic properties. On steam distilling the dry flowering shoots of these plants, very little of the essential oil was obtained. The results of detailed studies on these plants will be communicated in due course.

ACKNOWLEDGEMENTS

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A NEW METHOD FOR THE DETERMINATION OF THE AVERAGE DIAMETER OF TEXTILE FIBRES, FILAMENTS, FINE WIRES, ETC.

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(With three text-figures)

The fineness of the cotton fibre which is determined by the diameter of the original cell is a very important criterion of the spinning quality of a sample of cotton, especially in the long staple cottons. The method of studying this character is generally the microscopical method which is not only strenuous but time absorbing and for this reason the fibre diameter is not generally studied. The object of the present investigation is to develop a method by means of which the average diameter of a large number of fibres could be determined accurately and quickly. The method developed is applicable not only for cotton fibres but also for other fibres hairs, fine wires, etc.

THEORY

The theoretical basis of the present investigation is as follows. A beam of light of uniform intensity passing through an accurately made slit falls on a photoelectric cell and the photoelectric current (I_1) produced is measured. If it is assumed that the current is proportional to the area of illumination, then

$$I_1 = k.\,wl \qquad \text{......................(1)}$$

where k is a constant and w and l are the width and length of the slit respectively. Next a parallelised tuft of opaque fibres, filaments, etc., with as little overlapping as possible, is interposed in the path of the beam perpendicular to the length of the slit. The area of illumination is now reduced by an amount equal to $n\,w\,d$, where n is the number and d is the average diameter of the material under study. If the intensity of illumination remains the same as before the current, I_2, is given by

$$I_2 = k\,(wl - n\,w\,d) \qquad \text{..........................(2)}$$

From (1) and (2) it follows that

$$d = \frac{l}{n} \cdot \frac{I_1 - I_2}{I_1} \qquad \text{..........................(3)}$$

The terms on the right hand side of (3) are all known excepting n, which can be counted either with the naked eye or with the help of a low-power microscope and from the knowledge of this d can be calculated.

The two assumptions necessary to satisfy this equation are (1) that the fibres, filaments, etc. are opaque to the light and (2) that there is not any appreciable overlapping. If the fibres are not originally opaque it may be possible to render them opaque by dyeing. The condition for avoiding the overlapping may be satisfied either by mounting the fibres, filaments, etc., individually or by taking sufficient care in the process of parallelisation to ensure that there is not appreciable overlapping. In actual practice it is possible to satisfy both these conditions in most cases.

EXPERIMENTAL

(a) *Apparatus.* The apparatus shown schematically in Fig. 1 essentially consists of a hollow cylinder supported on two uprights. An electric lamp placed at one end of the cylinder is fed with a constant current of 1·8 or 1·9 amperes from an 18 volt storage battery. A fine variable resistance and a sensitive ammeter are used in the circuit to maintain the current constant, which is essential for the accuracy of the final result. A condenser and suitable diaphragms are provided to obtain a beam of light of uniform intensity which is made to pass through a water-cell for absorbing the heat rays. The light emerging from the water-cell passes through an accurately made slit, 30 mm.

long and 5 mm. wide. The plate of this slit is provided with a suitable stand for holding the slide on which the fibres, filaments, etc. may be mounted. These slides can be interchanged rapidly to enable a fairly large number of readings to be taken on the same or different materials. The light emerging through the slit falls on the photoelectric cell, placed at the other end of the cylinder as near the slit as possible. The cell is of the Weston 'Photronic' type and is connected in series with a resistance of about 500 ohms to a Cambridge and Paul ballistic galvanometer, with a shunt of 100 or 150 ohms.

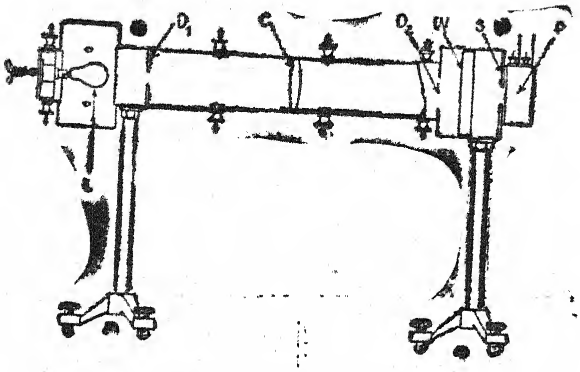

FIG. 1. The apparatus shown schematically

(*b*) *The slide and its use.* The slide mentioned above is an important feature of the apparatus as it helps the preparation, within a few minutes, of a parallel tuft of cotton fibres with very little overlapping, which is a serious source of error in this work. It is a modification of the Ahmad and Gulati [1936] slide, with velveteen pads in place of the fibre pads. As shown in Fig. 2 it consists of two pairs of pads A and B. At the commencement the upper pads of A and B are removed and the lower pads are kept flush to each other. A thin tuft of about 150 fibres, one layer thick, is extracted from a prepared sliver by means of a tweezer and is placed carefully on the slide such that the aligned end caught by the tweezer lies on the fixed pad A, near its edge and that the fibres lie without overlapping on the movable pad B, perpendicular to the edge. Now the upper pad of A is inserted and screwed on to hold one end of the fibres tightly. Next the upper pad of B is also inserted and pressing it gently B is pulled apart from A slowly until the required length of the fibres is exposed, when the upper pad of B is screwed tightly. Now holding A and B apart such that a small tension is exerted on the fibres, B is fixed in this position. The combing action on the fibres when pulled through the velveteen pads effects good separation and parallelisation and the whole process gives a tuft of parallel stretched fibres with little overlapping.

In the later work the overlapping was further reduced by using the following technique. The fibres mounted in the slide as stated above were viewed with a pair of binocular magnifying glasses and the fibres found overlapping were separated out with a needle. A few fibres that continued to overlap and a few short fibres that did not occupy the whole region between the pads were pulled out with a pair of fine forceps. By this procedure the overlapping was made very small.

It should be stated, however, that the overlapping cannot be reduced beyond a certain minimum. It is, therefore, necessary to determine the average number of fibres that lie across a certain section of the slide. For this purpose the number of fibres was counted by moving the slide under the microscope perpendicular to the length of the fibres, very low magnification being used so as to bring the fibres in the different planes within the focus. While counting, the fibres crossing the pointer end of the pointer eye-piece were examined carefully. If two fibres overlapped completely at this point they were counted as one. If, however, the overlapping was partial discretion was used to allot the number but this certainly is a source of error. It will be found later that though this error was perceptible with the first method of mounting, it almost completely disappeared with

the improved technique. The counts were made at three sections along the length of the fibre and the mean of the three was finally taken as the average number.

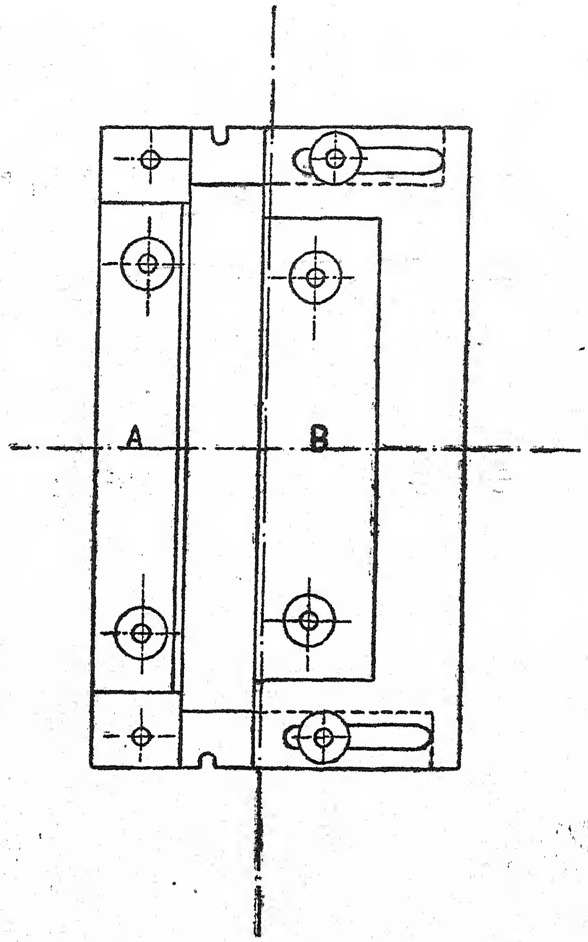

FIG. 2. The diagram of the slide

(c) *Mercerising and dyeing.* The cotton samples were first mercerised with 18 per cent caustic soda solution in order to make the cross-section of the fibres nearly circular. After washing, scouring and washing again the fibres were made opaque by dyeing in a boiling solution of chlorozol black for about 15 minutes. Material other than cotton which was not opaque was also dyed similarly. The dye solution contained by weight 1 per cent chlorozol black dye, 10 per cent glauber salt crystals and 89 per cent distilled water. About 10 c.c. of the solution were used for about 100 mg. of the cotton ample. After dyeing the cotton was washed in running water until the water was free from colour. The cotton was then squeezed out by hand and dried in an oven at a temperature of about 105°C.

Whether the dyeing process modified the fibre diameter to any appreciable extent was the next point to be ascertained. This was done by finding the diameter of several samples of cotton microscopically both before and after the dyeing but the values obtained showed no significant variation.

(d) *Photoelectric current or voltage.* Before taking up the actual work one point had to be decided, namely, whether to use the current or the voltage characteristic in the present study. A preliminary enquiry was, therefore, made and the diameter was calculated using both the properties.

When these values were compared with the values of the diameter as determined microscopically, it was found that the diameter calculated from the current agreed more closely. Besides the variability between the individual readings was found to be less in the case of the current values. Moreover the values of the diameter obtained from the voltage data were, in all cases, less than those from the current data, which divergence is found to have a theoretical basis as shown in the Appendix. Furthermore the makers of the 'Photronic' cell also advocate the current characteristic as it is less influenced by temperature changes. In addition to these, the experimental arrangement for the determination of the voltage is much more cumbersome than that for the current, which, within the limits of the present study, was found to be proportional to the galvanometer deflection. Hence both from the practical and from the theoretical points of view, the current characteristic is to be considered the more reliable criterion and, therefore, that has been used in the present investigation.

(*c*) *Proportionality of the photoelectric current and the area of illumination.* The next point to be decided was whether the photoelectric current produced was proportional to the area of illumination when the intensity of the source of light was kept constant. This was done in two ways, firstly by reducing the length of the slit by pasting strips of black paper at the two ends and secondly by interposing across the slit varying numbers of brass rods of average diameter 0·089 cm. In the former case the slit remains a continuous one while in the latter it becomes discontinuous. The results obtained are graphically represented in Fig. 3. The 45° line denotes absolute proportionality and it will be noticed that in the case of the continuous slit the curve departs very little from this line except when the area of the slit is as small as about 50 per cent of the whole slit. In the case of the discontinuous slit also the departure from proportionality is small when the decrease in the area is small but it becomes pronounced when the decrease in area is large. The theoretical basis for this departure with reduced illumination in both cases is probably due to the corresponding increase of photo-cell resistance. Whether the greater divergence observed in the case of the discontinuous slit is real or is due to experimental errors requires to be determined. If it is real, whether it is due to diffraction causes is considered in the next section. But this point is not material for our present purpose for within the limits of the present studies, namely, up to about 80 per cent of the area of the full slit, the photoelectric current is, for all practical purposes, proportional to the area of illumination.

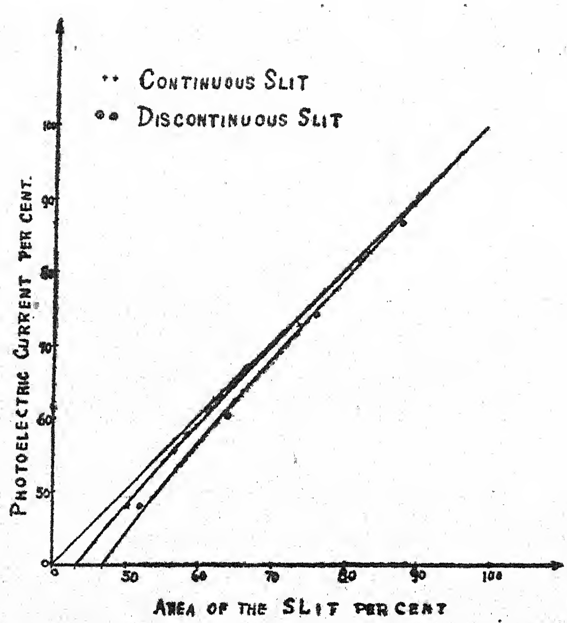

FIG. 3. The relation between photoelectric current and slit area

(*f*) *Effect of diffraction.* The greater divergence from the proportionality of the current and the area of illumination observed above in the case of the slit superposed with a few rods leads one to suspect that the departure may be due to diffraction causes. If the diffraction caused by the few rods produced such an amount of variation, then the large number of fibres should really produce considerably greater variation. But when the values of the diameter obtained by the photoelectric method were compared with those obtained microscopically it was found that, in all cases, the difference was small and within experimental errors. This means that the effect of diffraction is not as large as expected. It should be so from *a priori* considerations also, for what the diffraction does is not to destroy any energy but simply to shift the point of incidence. Moreover in the apparatus the diffraction effect has been made as small as possible by placing the photoelectric cell very near the slit, the distance between the latter and the active surface of the cell being hardly 5 mm.

(*g*) *Method of procedure.* In the preliminary studies for the accurate determination of the diameter, single filaments, fibres and wires were mounted individually using a heated mixture of sealing wax and paraffin wax. In the work on cotton fibres the slide mentioned above was used. Generally five determinations of I_1 and I_2 were made alternately for each test. In the case when individual filaments and wires, etc., were mounted four such tests were made on each slide. On the other hand, for the cotton samples four separate slides were tested for each sample. In each case the diameter of the material was also determined by means of the microscope for purposes of comparison.

(*h*) *Material.* The materials studied covered a wide range from the point of both substance and diameter. They were copper wire, silver wire, human hair, wool fibres, natural and artificial silk filaments and several samples of cotton fibres. The diameter ranged from 12μ to 117μ. In the case of the cotton samples, the standard Indian cottons ranging from the coarsest to the finest were examined in two sets. While for the second set of ten samples the improved technique of mounting was employed it was not used for the first set of 15 samples.

About 100 mg. of the cotton sample was found sufficient for the test. Cleaning and separation of the fibres before mercerising and dyeing considerably aided the preparation of the sliver afterwards. The front delivery roller (No. 33) of the draw box of the Balls sorter was made of half its usual diameter to facilitate the preparation of the small sliver.

Results

(*a*) *Fibres, filaments, etc.* The mean values of the diameter along with the standard errors for the fibres, filaments, etc., are given in Table I.

Table I

Diameter (in μ) of fibres, filaments, wires, etc.

No.	Substance	Photoelectric * P	Microscopical ** M	Difference $P-M$
1	Natural silk	12·4±0·13	12·2±0·24	+0·2±0·27
2	Wool fibre	24·0±0·56	23·3±0·36	+0·7±0·67
3	Art silk	24·4±0·69	24·3±0·96	+0·1±1·22
4	Ditto	26·4±0·11	26·4±0·47	0·0±0·48
5	Silver wire	47·2±0·53	47·3±0·21	—0·1±0·57
6	Human hair	74·3±0·87	75·7±0·63	—1·4±1·07
7	Copper wire	124·6±1·35	116·7±0·73	+7·9±1·53

* Mean of four tests on one slide
** Mean of all the material mounted on the slide

It will be noticed that the diameter of the materials ranges from 12μ to 117μ and in all cases except for the copper wire the difference between the value obtained by the photoelectric method and the microscopical method is non-significant indicating a close agreement between the two sets of values. The significantly higher value obtained by the photoelectric method for the copper wire is probably due to the fact that the wires were not perfectly straight. The slight bend would increase the length of the wire by a small amount but for purposes of calculation the length is taken as 5 mm. only. The consequent error is reflected in the higher value of the diameter obtained.

(*b*) *Cotton samples.* The values of the fibre diameter obtained for the first 15 cottons are recorded in Table II and the analysis of variance of the data is given in Table III.

TABLE II

Diameter (in μ) of cotton fibres by the photoelectric and microscopical methods : Fifteen Standard Indian Cottons of 1935-36 and 1936-37 seasons

No.	Cotton	Photoelectric * P	Microscopical ** M	Difference $P-M$
1	*Verum 262, Nagpur (1935-36)*	15·5±0·44	15·3±0·22	+0·2±0·49
2	*Mollisoni*	18·5±0·57	18·8±0·31	—0·3±0·65
3	*Umri Bani*	15·1±0·34	15·6±0·27	—0·5±0·43
4	*Co. 2 (1936-37)*	15·8±0·49	15·5±0·26	+0·3±0·55
5	*Sind N. R.*	17·9±0·19	18·6±0·27	—0·7±0·33
6	*Surat 1027 A.L.F.*	17·1±0·17	17·1±0·28	0·0±0·33
7	*Hagari 1*	15·7±0·91	15·6±0·30	+0·1±0·96
8	*Karunganni C.7*	15·6±0·85	15·7±0·24	—0·1±0·88
9	*Nandyal 14*	14·4±0·41	14·1±0·21	+0·3±0·46
10	*C.402*	15·5±0·51	15·6±0·25	—0·1±0·57
11	*Verum 434 (Akola)*	15·8±0·80	15·8±0·22	0·0±0·83
12	*P.A. 289F*	13·9±0·48	13·4±0·19	+0·5±0·52
13	*Co. 2 (1935-36)*	15·3±0·53	14·4±0·24	+0·9±0·58
14	*Wagad 8*	18·8±0·28	18·3±0·42	+0·5±0·50
15	*Verum 262, Nagpur (1936-37)*	15·4±0·38	15·3±0·22	+0·1±0·44
	Mean	16·01	15·93	+0·08±0·41

* Mean of four slides ** Mean of about 150 fibres

TABLE III

Analysis of variance of the photoelectric values for the 15 cottons

Variance due to	Degrees of freedom	Sum of squares	Mean square	S. D.
Cottons	14	561·6049	40·1146	..
Between slides	45	51·4115	1·1425	1·069 (6·7 per cent)
Within slides	240	64·7720	0·2699	0·5195 (3·2 per cent)
Total	299	677·7884	..	..

It will be noticed (Table II) that the fibre diameter varies from 14·4μ to 18·8μ among the 15 cottons. In all cases the difference between the photoelectric value and the microscopical value is not significant. The mean difference for all the 15 cottons taken together is ±0·08, ±0·41 which is also non-significant. This means that, as with filaments and wires, in the case of the cotton fibres also the value of the diameter obtained by the photoelectric method agrees closely with that obtained microscopically.

Next if the analysis of variance is considered it will be seen (Table III) that the variance between cottons is significant and also large, as is to be expected with the wide range of cottons studied. The variance between slides is also significant showing that the difference between slide and slide is definitely more than the error of the experiment with one slide. The former is made up of three factors, (1) the photoelectric error of the determination, (2) the error due to the variation of the fibre diameter within a sample of cotton and (3) the error caused by the overlapping of the fibres. Of the three, the second is incident in the sample and cannot, therefore, be overcome. The first one is due to the method of measurement employed. In the present work this error is 3·2 per cent for a single set of observations or 1·43 per cent for the mean of five such observations. It may possibly be reduced further by using more precise arrangement for maintaining constant current in the lamp. Even as it is, it is of the same order as that obtained by the microscopical method when about 150 fibres are examined. Therefore, this factor too cannot be considered large. Coming to the third factor it should be pointed out that in the present 15 samples of cotton, the fibres were separated and parallelised by merely pulling them through the moving pair of pads of the slide. The improved technique of mounting by means of which the overlapping and short fibres were eliminated was not used in this case. It was used for another set of ten cottons, the results for which are given in Table IV, the analysis of variance being shown in Table V.

TABLE IV

Diameter (in μ) of cotton fibres by the photoelectric and microscopical methods : Ten standard Indian cottons of the 1943-44 season

No.	Cotton	Photoelectrical * P	Microscopical ** M	Difference $P—M$
1	*Jayawant*	15·2±0·30	15·4±0·25	—0·25±0·39
2	*Surat 1027 A.L.F.*	17·3±0·36	16·9±0·31	+0·4±0·48
3	*Nandyal 14*	14·1±0·22	14·4±0·31	—0·3±0·38
4	*Wagad 8*	17·8±0·30	18·1±0·32	—0·3±0·44
5	*Jarilla*	15·2±0·35	15·0±0·28	+0·2±0·45
6	*Gadag 1*	14·4±0·32	13·7±0·20	+0·7±0·38
7	*Co.2*	14·8±0·36	14·0±0·29	+0·8±0·46
8	*Sind Sudhar*	13·1±0·36	13·0±0·20	+0·1±0·41
9	*P. A. 298F/K.25*	14·4±0·31	13·8±0·23	+0·6±0·39
10	*Mollisoni*	17·6±0·27	17·3±0·28	+0·3±0·39
	Mean	15·39	15·16	+0·23±0·41

* Mean of four slides ** Mean of about 150 fibres

TABLE V

Analysis of variance of the photoelectric values for the ten cottons

Variance due to	Degrees of freedom	Sum of squares	Mean square	S. D.
Cottons	9	476·3364	52·9263	..
Between slides	30	12·1780	0·4059	0·637 (4·1 per cent)
Within slides	160	57·6280	0·3602	0·600 (3·9 per cent)
Total	199	546·1424		

It will be noticed (Table IV) that in the case of these ten samples of cotton also the difference between the values of the diameter obtained by the photoelectric and microscopical methods is not significant. The mean difference for the ten cottons taken together is $+0\cdot23 \pm 0\cdot41\mu$, this is also non-significant as was found previously (Table III). On the other hand, the variance between slides is not significant unlike what was found before, which means that the improved method of mounting by eliminating the overlapping or by reducing it to a minimum has considerably lessened this error. The standard deviation between slides is 1·1 per cent which gives a critical difference ($P \pm 0\cdot05$) of about 1·8, 1·2, 1·0, 0·9 and 0·8 for the mean of 1, 2, 3, 4 and 5 slides respectively. Hence if two slides are tested for one sample of cotton a critical difference of $1\cdot2\mu$ is to be expected which amount of accuracy is sufficient for practical purposes. If, however, greater accuracy is needed more slides have to be tested.

It will be observed that the photoelectric error in the case of these ten cottons is 3·9 per cent which is of the same order as was found in the previous case for the 15 cottons.

Discussion

From the foregoing it is clear that the method of finding the diameter described above gives accurate results, the values obtained agreeing closely with those got by the microscopical method. Besides the errors involved are also small enough for practical purposes. Furthermore this method has additional advantages over the microscopical method, namely, that considerably greater number of fibres are examined and that the average diameter over a long region of the fibres is obtained by this method. The time factor, however, has not been considered so far and it may be done now. The time taken for the photoelectric readings is hardly ten minutes for one slide. If the 'photronic' cell is good, the current for repeated exposures remains absolutely constant. In such a case it is not necessary to insert the slide containing the fibres and remove it alternately to get the readings of I_1 and I_2. The five readings of I_2 can be taken one after the other and half the readings of I_1 can be taken before and the other half after taking the I_2 readings. This will reduce the time still further. The time for mounting the fibres is about ten minutes per slide. By mounting two slides one after the other and testing the two also one after the other, time could be saved. The time involved in taking the sample and in the preparation of the sliver is common to all the methods of study. The extra time necessary in the present work is that required for the mercerisation and dyeing of the sample. As this is a routine process it can be handed over to a skilled attender, if a large number of samples are to be examined. It follows, therefore, that apart from the time taken for other preliminary work, the actual time for the measurement is about 40 minutes (which can be reduced by practice) for one sample of two slides. This is small enough to enable the testing of a large number of samples. It should be mentioned, however, that the observer should be intelligent and should make the adjustments with great precision.

It can be concluded that the method developed in the present study is accurate, has a small experimental error and is quick enough for routine testing of a large number of samples.

Before closing it should be mentioned that it is easily possible to improve the accuracy of the instrument by having a differential arrangement with two photoelectric cells instead of one. By this means the difference in current, $I_1 - I_2$, is measured and by using a more sensitive galvanometer the deflection may be made large enough to be free from errors of measurement. It will involve some small alterations in the apparatus which can be easily made.

Summary

The fineness of the cotton fibre, as expressed by its diameter is an important character, especially in the case of the long staple cottons. A new method has been developed for determining quickly and accurately the mean diameter of a large number of fibres, which is applicable not only to cotton fibres but to other textile fibres, filaments, fine wires, etc.

In this method a uniform beam of light passing through an accurately made rectangular slit falls on a photoelectric cell producing a current I_1. A parallel bundle of opaque fibres, filaments, etc., with as little overlapping as possible, is interposed in the path of the beam perpendicular to the

length of the slit. The photoelectric current is reduced to I_2 depending upon the number, n, and the average diameter, d, of the fibres. If the intensity of the light source remains the same and if l is the length of the slit, it can be easily shown that

$$d = \frac{l}{n} \quad \frac{I_1 - I_2}{I_1}$$

The number, n, can be counted under a low-power microscope and the diameter can be calculated.

The apparatus, designed at the Technological Laboratory, consists of a hollow tube with an electric lamp, fed with a constant current, at one end. The light is rendered uniform by means of a condenser, and after passing through a water-cell for absorbing the heat rays, emerges through the slit and falls on a photoelectric cell of the Weston Photronic type. The current generated is measured on a galvanometer. The slit contains an arrangement to hold a slide for mounting the material. A special slide has been made by means of which fibres can be mounted quickly with very little overlapping. Transparent or semi-transparent fibres are rendered opaque by dyeing them with a suitable black dye, which does not affect their diameter.

Using the apparatus the average diameter of many textile fibres and other materials covering a wide range of values from 12μ to 117μ have been measured. Their diameters were also determined microscopically for purposes of comparison. In all cases the values obtained by the photoelectric method were not significantly different from those microscopically obtained. The method is found to give accurate results with a small experimental error and is quick enough for routine testing of a large number of samples.

Acknowledgements

Some preliminary work in connection with this study was done by late Mr. G. Rama Rao.

Reference

Ahmad, N. and Gulati, A. N. (1936). *J. Text. Inst.* **XXVIII,** T 109-111

Appendix

The fibre diameter, d_i, obtained from the values of the proelectric current is given by equation (3), that is

$$d_i = \frac{l}{n} \quad \frac{I_1 - I_2}{I_1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

If V_1 and V_2 are the respective photoelectric voltages, without and with the fibres respectively, and if d_v is the value of the diameter obtained from them,

then

$$d_v = \frac{l}{n} \quad \frac{V_1 - V_2}{V_1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

If R_1 and R_2 are the respective resistances of the photoelectric cell, $V_1 = I_1 R_1$ and, $V_2 = I_2 R_2$

Therefore

$$d_v = \frac{l}{n} \quad \frac{I_1 R_1 - I_2 R_2}{I_1 R_1}$$

By dividing both the numerator and the denominator by R_1

$$d_v = \frac{l}{n} \cdot \frac{I_1 - I_2 \dfrac{R_2}{R_1}}{I_1}$$

By adding and subtracting R_1

$$d_c = \frac{l}{n} \; \frac{I_1 - I_2\left(\frac{R_1+R_2-R_1}{R_1}\right)}{I_1}$$

$$= \frac{l}{n} \; \frac{I_1 - I_2\left(\frac{R_2-R_1}{R_1}\right)}{I_1}$$

$$= \frac{l}{n} \; \frac{I_1-I_2}{I_1} - \frac{l}{n} \; \frac{I_2}{I_1} \; \frac{(R_2-R_1)}{R_1}$$

Since from (4) the first term on the right hand side is equal to d_1

$$d_c = d_1 - \frac{l}{n} \; \frac{I_2}{I_1} \; \frac{(R_2-R_1)}{R_1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Now R_2 is the resistance of the photoelectric cell with the lower illumination and, is, therefore, greater than R_1, the resistance with the higher illumination. Hence R_2-R_1 is positive which makes $\frac{l}{n} \; \frac{I_2}{I_1} \; \frac{(R_2-R_1)}{R_1}$ positive. This positive quantity is subtracted from d_1 to give d and therefore the latter is smaller than the former as is experimentally found to be the case.

REVIEW

IMPERIAL BUREAU OF SOIL SCIENCE TECHNICAL COMMUNICATION NO. 43

Land Classification for Land-Use Planning BY G. V. JACKS

(Published by the Imperial Bureau of Soil Science, Harpenden, England, 1946. Price 4*s.* 0*d.*)

LAND classification is of vital importance for land-use planning. The land and water resources of a country constitute the national heritage of the people living in it. An inventory has to be made of them by requisite surveys, they have to be preserved against loss and damage and utilized to the best advantage consistent with such conservation and handed down to posterity in an unimpaired, if not, improved state. The objective of a land-use plan must be clearly visualized and the rival demands on these resources have to be properly balanced, taking into consideration the trends of development of their use and local, regional and national needs. 'Land classification must form the starting point of land-use planning.' In the ultimate analysis the improvement of soil fertility and its maintenance at the optimum level must be the main foundation of plans of land use at least in so far as the production of plants of economic importance is concerned. With our population of 400 millions and annual increase at the rate of five millions and with the yield per acre of almost all our crops one of the lowest of that achieved in most countries, this question of conservation of land and of soil fertility obviously assumes national importance. There are various types of land classification in vogue, some of them based 'on considerations of economic factors, transport facilities and many others'. 'It is however usual to distinguish between physical, and the economic and social classification of land.' 'The physical or 'inherent' characteristics include the geology, climate and topography and are permanent in the sense that they cannot be profoundly altered by man. Geology, climate and topography are combined in the factor soil, which, though to some extent modifiable by man or other living organisms, is the main factor in a physical classification. A physical land classification is permanent, and once made can serve as the basis on which to superimpose an economic and social classification which will need to be modified with changes in economic and social conditions (e.g. market conditions and communications) as well as with the changes in the objective of the plan that may occur as the plan unfolds.' The economic standpoint is of course most relevant and 'important as it is essential to recognize that in planning optimal land use and

its success depends on economic soundness'. But 'the factors to be taken into account in economic and social classification will vary both as to their nature and the weight to be attached to each with the social objective of the plan'. 'In some instances, markets, in others communications, in others tradition and custom, in others political questions, may constitute the dominant factor, and there will always be many variable and fluctuating subsidiary factors.' 'Among the essential economic data are included uses of land, kind of ownership, land values, transportation facilities and markets for present and potential products; and among social data, distribution and kind of population, both rural and urban, and economic status (standard of living) of rural classes.' 'Such things as the passing of the physical frontier, the change of a country from debtor to creditor status, the loss of foreign markets, the approach to a stable population and the conflicts that arise in the national economy of a country between capital and labour' also require consideration. But 'by its very nature social-economic land classification must be labile and indefinite'. Land-use varies from time to time and is governed by a multiplicity of considerations. 'Classifications based on use-capabilities in order that it has to be of long-term validity' should also allow for probable developments in technique and science.

The approach that the U. S. A. Department of Agriculture, especially through its Soil Conservation surveys, has made towards the formulation and effectuation of land-use plans, is 'the best known and most successful'. It is based on a sample physical classification and 'social and economic factors do not enter into the land classification, but they do enter into the effectuation of the plan, and may necessitate modifications in the 'ideal' plan based on strict adherence to the physical land classification. The plans are made and carried out by the occupiers of the land themselves who can call upon outside experts to give advice and direction if required'. 'The prime objective of every soil conservation district plan is the same to save the soil from exhaustion and erosion.' 'In July 1945, 3,404,000 farms covering 734 million acres were included in the 1,328 soil-conservation districts which had been set up.' There are many other examples of land-use planning, e.g. that in use in Russia by some Russian collective farms (Kolkhozes). 'These plans are coordinated into a national plan by the central planning authority (Gosplan).' 'The kolkhoz is required to produce certain amounts of certain crops and is expected to adopt certain rotations and farming practices which have been shown to conserve soil fertility in the region concerned.' 'Under such circumstances a physicial land classification to suit the pre-conceived plan which may be modified within limits to fit the land classes can readily be made. Social-economic factors enter to a variable but usually only to a minor extent.' There are other cases 'where the objective is less clear or less clearly related to definite uses of land, the land classification tends to be correspondingly vague'; and 'an objective such as the common welfare, the public good, the improvement of the standard of living, or merely the optimal uses of land forms an insufficient basis for a land classification'. 'There is no such thing as a general land classification, but there is a common physical classification appropriate as a basis for land-use plans aiming to promote and perpetuate the public welfare and therefore requiring the maintenance of soil fertility. Superimposed on this basis is another social-economic classification which is, in effect, part classification and part planning. It is often difficult to know where the process of land classification ends, and that of land planning begins.'

The extracts given above will convey an idea of recent trends in land classification for agricultural purposes. A very comprehensive account is given on the different aspects of land classification and the factors which govern it and of its objectives. The subject-matter has been discussed under the following heads:

Land classification and land-use planning

Types of land classification

The physical classification of land

Land inventories

The U. S. Soil Survey

Land types and soil types

Land types and genetic soil types
Land-use classes
Agricultural Regions
The estimation of population capacity
Population and land quality
The use of natural vegetation as an indicator of land quality
Plant indicators of forest-site quality
Grassland indicators
System of land classification :

1. Michigan
2. U. S. Soil Conservation Service
3. Tennessee Valley Authority
4. New York State
5. Western Canada :
   Saskatchewan
   Alberta
6. Ontario
7. New Zealand
8. Great Britain
9. Prussia
10. Land classification for irrigation purposes

The Estimation of Productivity :
 Productivity ratings
 The Storie index
 Canadian rating systems :
  Saskatchewan
  Alberta
 Ranking Coefficients
 German soil ratings—Bodenbonitierung

This publication is most welcome and especially opportune at this moment. The information on land classification is scattered in publications in different languages and Mr Jacks has done a great service to all interested in the subject by collating them together and elucidating them with his comments. The approach has, however, been mainly factual.

PLANT QUARANTINE NOTIFICATIONS

Notice No. 1 of 1946. Notifications of Foreign Plant Quarantine Restrictions received in the Bureau of Plant Protection and Quarantines, Department of Agriculture, Government of India, New Delhi, during the period January to June 1946.

The following Plant Quarantine Notifications have been received in the Bureau. Those interested are advised to apply for details to the Plant Protection Adviser to the Government of India.

1. Gypsy moth and Brown-tail moth Quarantine: Domestic Quarantine Notice No. 45, dated 10th October, 1945: U.S.A. Deptt. of Agriculture B.E.P.Q. No. 72.	Restrictions to prevent spread of these moths in the United States.

2. Mexican Fruitfly Quarantine: Domestic Quarantine Notice No. 64, dated the 26th Nov. 1945: U. S. Department of Agriculture B. E. P. Q. No. 64.	Restrictions to prevent the spread of the Mexican fruitfly (*Anastrepha ludens*) outside the state of Texas.
3. White-Fringed Beetle Quarantine: Domestic Quarantine Notice No. 72, dated the 12th December 1945: U. S. Department of Agriculture B. E. P. Q. No. 72.	Restrictions to prevent spread of the White-fringed Beetle (*Pantomorus* spp.) in the United States.
4. Plant-Quarantine Import Restrictions of the Republic of Cuba: B. E. P. Q. No. 509—Supplement No. 2, dated 8th February 1946: issued by U. S. Department of Agriculture.	Referring to amendations of regulations governing the importation of seed-potatoes into Cuba.
5. Plant-Quarantine Import Restrictions of the Republic of Bolivia: B. E. P. Q. No. 484 (Revised), dated 8th February, 1946: issued by the U. S. Department of Agriculture.	Contains a digest of the plant-quarantine import restrictions of the Republic of Bolivia for the information of importers.
6. Plant-Quarantine Import Restrictions of Jamaica, British West Indies; B. E. P. Q. No. 547, dated the 21st March, 1946 (superseding B. P. Q.—355—Revised): issued by the U. S. Department of Agriculture.	Contains a revised summary of the plant-quarantine restrictions of Jamaica for the information of nurserymen, etc.
7. Plant-Quarantine Import Restrictions of the Kingdom of Egypt: B. E. P. Q. No. 375—2nd Revision, dated the 19th April, 1946: issued by the U. S. Department of Agriculture.	A Revision of the plant-quarantine import restrictions of the Kingdom of Egypt.
8. Plant-Quarantine Import Restrictions of the Republic of Mexico: B. E. P. Q. No. 411—Supplement No. 4, dated 25th April, 1946: issued by the U. S. Department of Agriculture.	Refers to certain amendments in the restrictions of the import of corn into Mexico from the United States on account of the European Corn Borer (*Pyrasta nubilalis*).
9. Plant-Quarantine Restrictions of the Ministry of Agriculture in Iran: Communicated by Consul General for Iran in India, dated 3rd June. 1946.	All plants and vegetables imported into Iran should be accompanied by certificates of freedom from various pests and diseases in list attached with the letter.

MGIPC—M—III-1-1—12-4-48—600.

ORIGINAL ARTICLES

CITRUS ROOTSTOCK TRIALS IN THE PUNJAB

III. THE INFLUENCE OF DIFFERENT ROOTSTOCKS ON THE VIGOUR AND CROPPING OF MARSH SEEDLESS GRAPEFRUIT

By SHAM SINGH,* B.Sc. (AGRI.), PH.D. (BRISTOL), Assistant Fruit Development Adviser to the Government of India and R. L. NAGPAL, B.Sc. (AGRI.), Research Assistant, Agriculture Department, Punjab

(Received for publication on 20 March 1947)

(With four text-figures)

CAPTAIN R. Mitchell [1946] of the Indian Mildura Fruit Farm, Montgomery, was probably the first to plant in 1925 a few trees of grapefruit in his orchard in the Punjab. A few years later, the Fruit Specialist, Punjab (Sirdar Bahadur Lal Singh), made several successful attempts in importing nursery trees of important varieties of this species from the U.S.A. for trials in the Punjab. As a result of these importations and trials, the Marsh Seedless variety gained sufficient prominence and popularity with citrus growers in the early thirties and the demand for budded trees of this variety increased tremendously by 1938.

Wherever grapefruit trees of this variety were planted in the Punjab, the quality of fruit produced was superb. The cropping was both regular and heavy and the trees were found to withstand adverse soil conditions better than even the Malta orange trees. These were some of the potent factors that prompted inclusion of this species in the rootstock trials reported by Lal Singh and Sham Singh [1942].

In western countries, particularly the U.S.A., the grapefruit is consumed as a breakfast fruit without an equal. It is an excellent appetizer and a stomachic. Its use is also finding favour with the people in India where, of late, it has been prescribed by physicians against malaria and as a blood purifier. The fruit ripens in the Punjab in the beginning of December and can be held on the trees till the end of March or even later if need be. It would, however, be better if the pickings are over by the middle of March so that the risk of shedding of flowers and fruit of the next crop is obviated.

It would be recalled that the results reported in the previous two articles in this series by Lal Singh and Sham Singh [1942 and 1944] pertained to the period when the trees were purely in their vegetative phase and, as such, the rootstock influence in case of various scion-stock combinations was reported in respect of 'tree vigour' only. Since then, data in respect of both 'tree vigour' and 'cropping' in case of all the four scions for a further period of four years have been collected and compiled. The present communication deals with such data in case of the Marsh Seedless grapefruit scion only. Similar information regarding the remaining three scions will be reported in due course as, due to various reasons, it was found impracticable to include it in this article.

With the commencement of fruit bearing, the rootstock influence is manifest in two different directions, *viz.*, increase in tree size on the one hand and fruit yield on the other. According to the programme laid down, data on both of these aspects has been and will continue to be collected year by year to study the relationship between these two aspects in case of different scion-stock combinations under trial. The underlying aim is to determine the suitability of a particular rootstock for a particular scion such that the increased production of fruit is consistent with tree vigour and longevity of trees in each case. The data reported here cover the period of first four years of fruit bearing in case of the Marsh Seedless grapefruit trees from 1940-41 to 1943-44.

MATERIAL AND LAYOUT

For details regarding the preparation of material and layout the reader is referred to a previous communication in this series by Lal Singh and Sham Singh [1942]. The various scion-stock combinations here under study are given in Table I.

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TABLE I

Different scion-stock combinations under trial

Field No.	Method of raising the rootstock	Name of scion-stock combination	No. of trees under study	English equivalents of root-stocks	Specific-names
4	Seed	Marsh Seedless on "Kharna Khatta" .	24	*nil*	*C. Karna* Raf.
,,	,,	Marsh Seedless on "Jatti Khatti"	24	Rough lemon . .	*C. limonia* Osbeck
,,	,,	Marsh Seedless on "Mitha" .	24	Sweet lime . . .	*C. aurantifolia* Var. Swingle
,,	,,	Marsh Seedless on "Mokari" .	24	Citron	*C. medica* Linn.
,,	,,	Marsh Seedless on "Chakotra" .	24	Shaddock . . .	*C. Maxima* Merril
9	Cutting	Marsh Seedless on "Kharna Khatta"	18	....	....
,,	,,	Marsh Seedless on "Jatti Khatti"	18	....	....
,,	,,	Marsh Seedless on "Mitha" .	18	....	....
,,	,,	Marsh Seedless on "Mokari" .	18	....	....

It is clear from the foregoing that the experimental material constituted two sets. In the one case the Marsh Seedless scion was budded on rootstocks raised from seed and, in the other, the same scion was budded on rootstocks propagated by the rooting of stem cuttings. The two groups of experimental material, thus prepared, where planted separately into two fields and treated as two independent and self-contained experiments. The results of both the trials are embodied in the present communication with a view to study the performance of the Marsh Seedless grapefruit trees growing on rootstocks propagated both from seeds and cuttings.

Data collected

The girth measurements of all the trees under investigation were taken at a fixed point above the union year by year [Lal Singh and Sham Singh, 1942]. The yield of trees was recorded by counting the number of fruits on each tree when they were still green and unripe so as to avoid the vitiation of results through such possibilities as pilferage and damage by birds, etc. The number of fruits was again counted at the time of picking and compared with yields recorded previously. This double check was found to be very helpful in having a correct idea of fruit yield in each case.

DISCUSSION OF RESULTS

The year to year data in respect of vigour (indicated by stem-girth measurements) and cropping (indicated by number of fruits borne per tree) of the Marsh Seedless trees as influenced by different rootstock in both the field trials are compiled separately in Tables II and III.

TABLE II

Tree size and cropping of the Marsh Seedless trees* growing on certain rootstocks propagated from seeds

Year of observation	Growing season	Rootstocks													
		Kharna Khatta		Rough lemon		Shaddock		Sweet lime		Citron		S.E.		C.D.	
		girth	yield	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield
1940	1939	18·7	..	18·3	..	16·6	..	14·7	..	12·4	..	0·48	..	1·50	..
1941	1940	27·7	25	27·2	9	25·1	11	19·7	22	15·4	14	0·52	..	1·50	..
1942	1941	35.2	58	35·3	42	32·6	46	23·6	36	18·8	14	0·78	5·42	2·3	11
1943	1942	41·0	219	41·8	141	38·6	119	26·0	43	20·9	29	0·86	15·6	2·8	46
1944	1943	44·4	363	46·5	263	42·6	239	27·9	78	22·5	49	1·12	14·8	3·3	44

* Planted in January, 1937

TABLE III

Tree size and cropping of the Marsh Seedless trees growing on certain rootstocks propagated from cuttings*

Year of observation	Rootstocks												
	Growing season	Kharna Khatta		Rough lemon		Sweet lime		Citron		S.E.		C.D.	
		girth	yield	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield
1940	1939	21·2	..	20·3	..	15·8	..	15·5	..	0·375	..	1·2	..
1941	1940	29·5	44	30·1	27	20·4	32	18·8	28	0·542	3·8	1·6	11
1942	1941	36·6	65	39·1	48	24·8	39	23·1	26	0·549	3·02	1·7	9
1943	1942	41·7	265	46·3	201	27·5	94	25·8	74	0·635	15·76	1·9	47
1944	1943	46·2	296	52·1	271	30·9	88	28·5	63	0·883	8·62	2·7	26

* Planted in January 1937

Comparison of data in Tables II and III

The data in tables II and III show that no crop was taken from the trees for the first four years (1937-1940). This gave the trees in both the field experiments sufficient time to build up mechanically strong framework. The first crop, picked in 1941, was a light one in each case but more so in case of trees growing on rootstocks propagated from seed. This point is significant in so far as it reveals the precocious nature of trees on rootstocks raised from cuttings which also developed better size during the period of vegetative phase than those on rootstocks raised from seed. To form an idea of comparative tree size and cropping of trees on both sets of rootstocks, the data in Tables II and III are amalgamated in Table IV.

TABLE IV

The comparative tree size and cropping of the Marsh Seedless trees growing on certain rootstocks raised both from seeds and cuttings

Rootstock under trial	Method of raising the rootstock	1941		1942		1943		1944	
		girth in cm.	yield	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield
Kharna Khatta	Seeds	27·7	25	35·2	58	41·0	219	44·4	363
do.	Cuttings	29·5	44	36·6	65	41·7	265	46·2	296
Rough lemon	Seeds	27·2	9	35·3	42	41·8	141	46·5	263
do.	Cuttings	30·1	27	39·1	48	46·3	201	52·1	271
Sweet lime	Seeds	19·7	22	23·6	36	26·0	43	27·9	78
do.	Cuttings	20·4	32	24·8	39	27·5	94	30·9	88
Citron	Seeds	15·4	14	18·8	14	20·9	29	22·5	49
do.	Cuttings	18·8	28	23·1	26	25·8	74	28·5	63

The data for girth and yield for all the four years show that the initial advantage in tree size and cropping in favour of trees on rootstocks raised from cuttings persists for the entire period and holds good for all the rootstocks under trial except in one solitary case in 1944 when trees on Kharna Khatta rootstocks raised from seed gave a higher yield. In other words, so far as tree size is concerned, the Marsh Seedless trees on rootstocks raised from seeds have not been able to catch up with the corresponding trees on rootstocks raised from cuttings. The same generally holds good in respect of cropping as well, except in one solitary instance out of sixteen comparisons when trees on "seedling rootstocks" outyielded those on "cutting rootstocks". These results show that size difference caused in the pre-orchard months may continue to persist much longer than is commonly known and believed. The same appears to hold good in respect of cropping as well. These points in favour

of rootstocks raised from cuttings appear to have a special significance so far as the performance of trees in early years at least is concerned. It would, however, be interesting to know whether and, if so, how long the trees on root stocks raised from cuttings would continue to remain in advantageous position both with regard to tree size and cropping. To throw further light on this aspect, the data in Tables II and III are plotted and are shown in Figs. 1 to 4. In Figs. 1 and 2, the size of trees from year to year, as indicated by trunk girth, is plotted and in Figs. 3 and 4, the yearly cropping in case of these very trees has been shown.

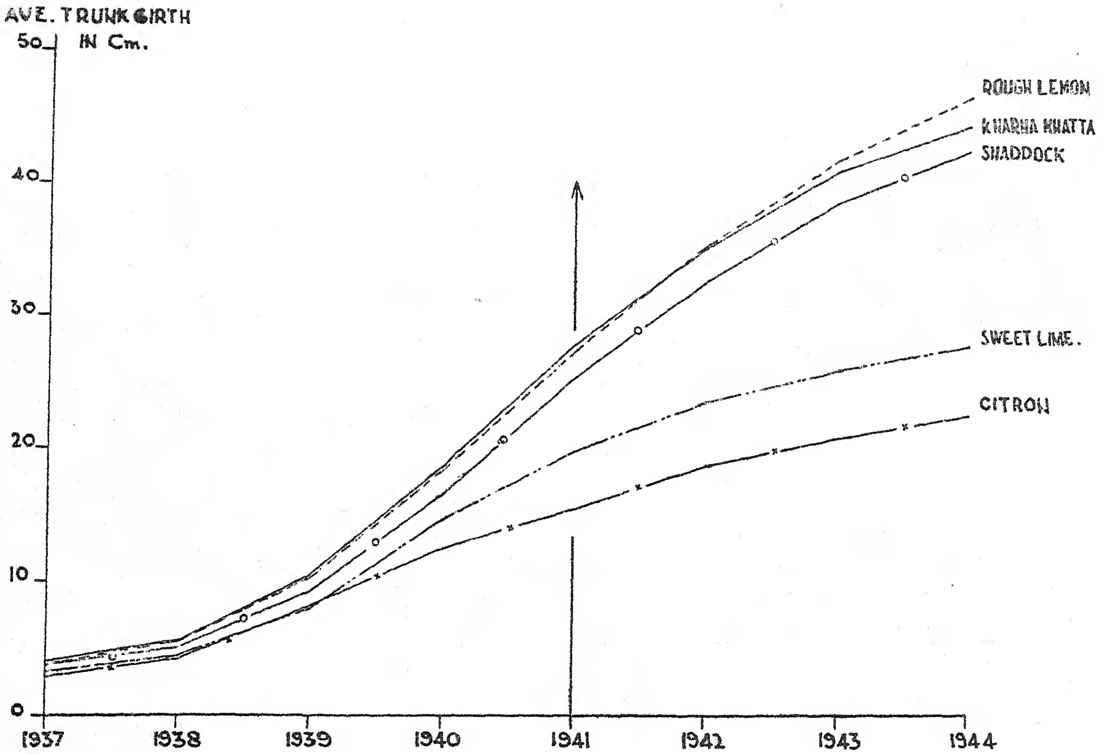

Fig. 1. Tree size on "Seedling Rootstocks"

The tree size. In Fig. 1 are plotted the data for tree size in respect of rootstocks raised from seed while in Fig. 2, similar data for rootstocks raised from cuttings have been shown. The rootstocks under study in both the experiments are identical except that in fig. 1 an additional rootstock, namely shaddock, is also included.

The data for tree size from 1937 to 1940, shown also in Figs. 1 and 2, have been fully discussed in a previous communication in this series by Lal Singh and Sham Singh [1942]. Briefly it may be stated that by the year 1940, considerable divergence or spread has been shown by the curves for rootstocks raised from seed (Fig. 1) so much so that the trees on five different rootstocks under study were classed by these authors in four different categories with respect to tree size. The divergence in growth curves in case of trees on rootstocks raised from cuttings (Fig. 2) is also well marked by 1940, and the four rootstocks here under study were found by Lal Singh and Sham Singh [1942] to fall in two groups only " Kharna Khatta " and rough lemon being in one group and sweet lime and citron being in the other.

The year 1941 was the first year of crop harvest in both the field experiments as shown by the arrow lines in Fig. 1 and 2. The curves in both the figures show a flattening tendency after 1941 indicating a fall in growth rate due to fruit production but the trees on rough lemon have been less affected than others. In view of this comparatively less decreased rate of growth in case of trees on rough lemon in both the field experiments, the tree size on this rootstock has comparatively improved

as compared to "Kharna Khatta", which was leading all rootstocks in this respect till 1941 in case of "Seedling Rootstocks" (Fig. 1) and till 1940 in case of "Cutting Rootstocks" (Fig. 2). By

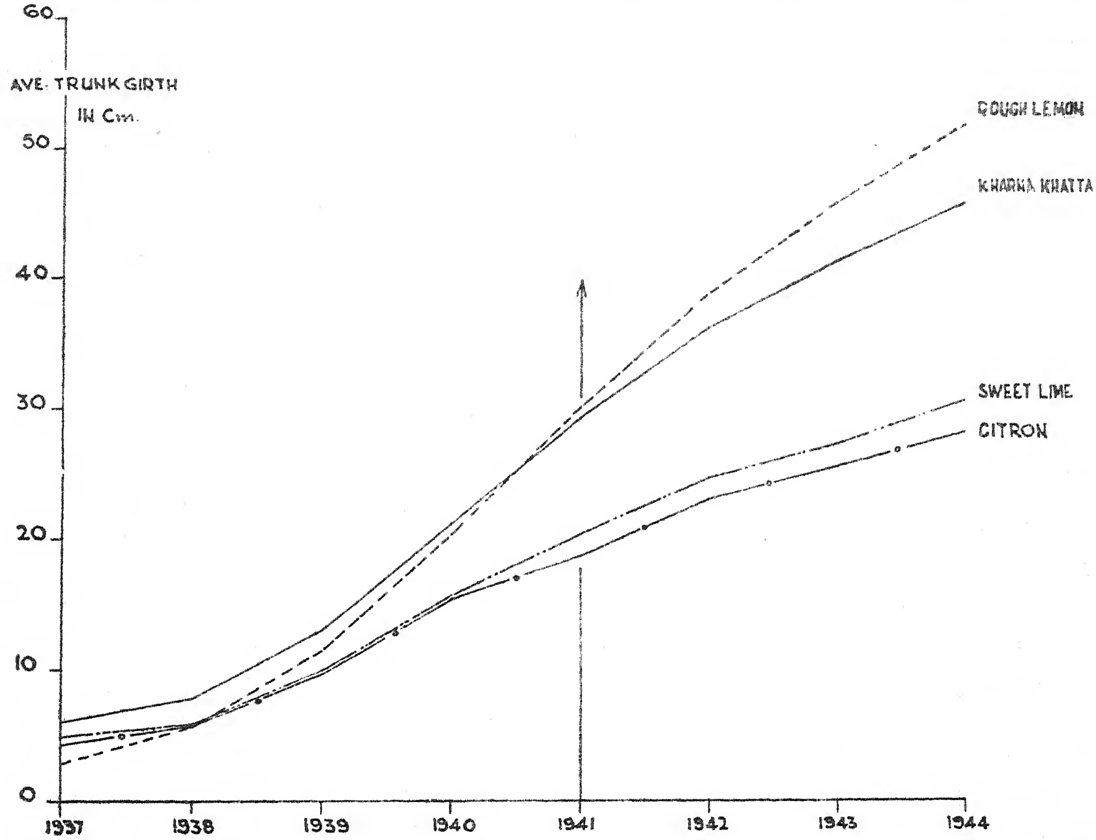

Fig. 2. Tree size on "Cutting Rootstock."

the end of 1944, the performance for tree size in case of rootstocks raised from seed (Figure 1) has not significantly changed from that reported earlier by Lal Singh and Sham Singh [1942], but that the trees on rough lemon rootstocks have all along been improving in size as compared to those on "Kharna Khatta". The performance for tree size in respect of rootstocks raised from cuttings has (Fig. 2), however, considerably changed since 1940. By 1941, the two dwarfing rootstocks have fallen in two distinct groups and this position has remained unaltered since then. The other two rootstocks associated with vigour of scion trees reversed position in 1941 and by 1942 the trees on rough lemon have been significantly more vigorous than those on "Kharna Khatta". This order of vigour has since been maintained by these two rootstocks.

The crop production

As has been previously stated, the fruit was harvested for the first time in 1941 in case of both the field experiments. The data for crop production in respect of rootstocks raised from seed are plotted in Fig. 3 while in Fig. 4, similar data for rootstocks raised from cuttings have been shown.

The crops had been rather sparse for the first two years of bearing—this being so in both the field experiments. But, as previously mentioned, the cropping was comparatively more in case of trees on rootstocks raised from cuttings. By 1943, the production increased considerably in both the experiments as is shown by a sharp rise of curves in both Figs. 3 and 4. This rate of production in case of rootstocks raised from seed (Fig. 3) has not only been maintained during 1944 but as the curves show there has also been a tendency for the trees on all the rootstocks to produce at a still

higher rate. On the other hand, in case of rootstocks raised from cuttings (Fig. 4), the rate of production in 1943 has not been maintained in 1944 by any of the four rootstocks under trial. In fact,

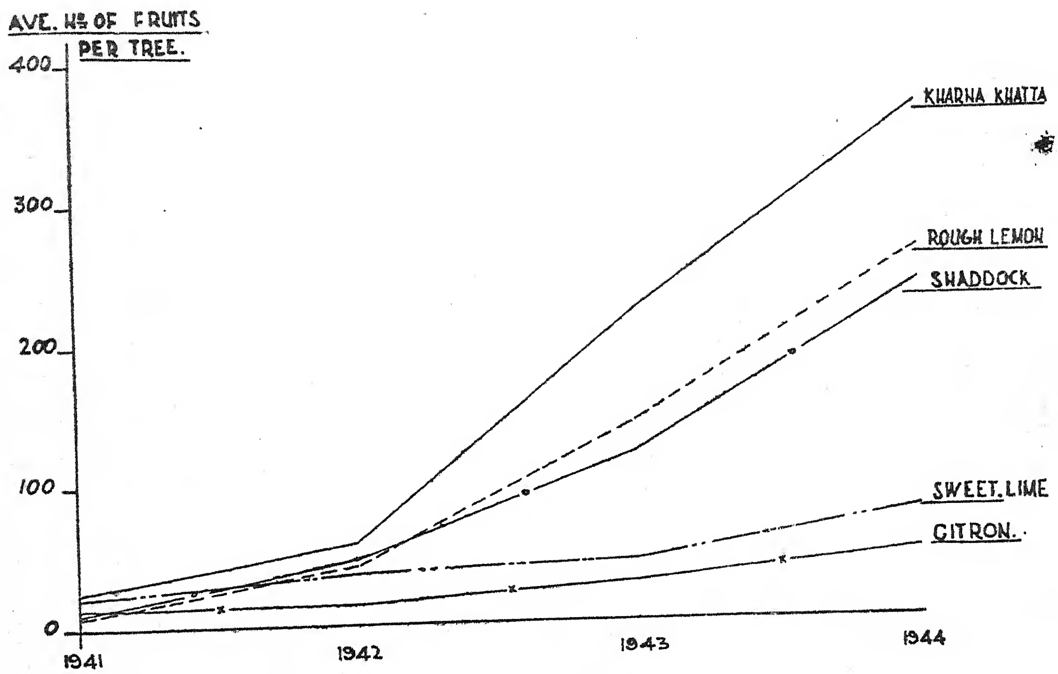

Fig. 3. Crop Production on "Seedling Rootstocks".

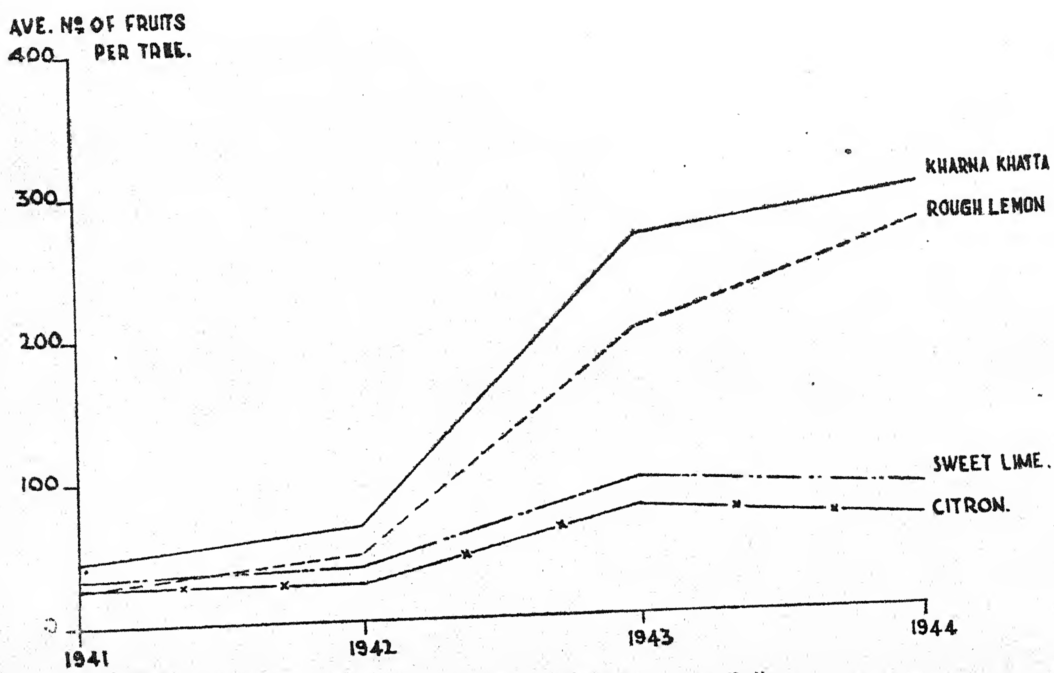

Fig. 4. Crop Production on "Cutting Rootstocks".

the productions in 1944 in case of sweet lime and citron had been actually less than those during the previous year. Therefore, the increased production in case of rootstocks raised from cuttings (Table IV) appears to be of transitory nature, but this passing phase may continue for some years more in view of the fact that size differences in favour of trees on rootstocks raised from cuttings may prove to be a determining factor for crop size at least for a few years more.

(B) The yearly growth increment in girth in relation to fruit yield

The data in Tables II and III reveal that the performance of various scion-stock combinations in respect of vigour and cropping is identical in both the field experiments except that the trees on rootstocks raised from cuttings have shown a depressed rate of crop production since 1943. Therefore, in the interest of brevity, detailed discussion regarding data for trees on rootstocks raised from seeds alone is made, as in this case five rootstocks are under trial as against four in the other set.

In the pre-bearing age, the entire metabolic activity of a tree is exclusively devoted to the production of vegetative growth. With the commencement of fruit bearing, however, a part of the products of metabolism are used in putting on new growth whereas the remainder are devoted to the production of fruit. In other words, the growth capacity of a tree may be reckoned as the sum total of the increase reflected in trunk-girth and production of fruit. Because of the competition in the use of synthesized food for vegetative growth and fruit production, it is of utmost necessity that both these aspects should be studied together in order that the rootstock influence in a given scion-stock combination be rightly assessed. It would be then and then alone that a correct appraisal of the comparative efficiency of various scion-stock combinations could be made. In view of this consideration the mean yearly increments in trunk-girth, along with the average fruit production for those years are compiled in Table V.

TABLE V

The mean increment in trunk-girth and average yield of the Marsh Seedless trees on rootstocks raised from seeds

Year of observation	Kharna Khatta		Rough lemon		Shaddock		Sweet lime		Citron	
	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield
1940	8·34	..	8·12	..	7·33	..	6·64	..	3·9	..
1941	9·0	25	8·9	9	8·5	11	5·0	22	3·0	14
1942	7·5	58	8·1	42	7·5	46	3·9	36	3·4	14
1943	5·8	219	6·5	141	6·0	119	2·4	43	2·1	29
1944	3·4	363	4·7	263	4·0	239	1·9	78	1·6	49

For the four-year period from 1937, when the trees were planted in the orchard, to 1940, *viz.*, so long as these trees remained in purely vegetable phase, there was a regular increase in the amount of growth put on by the trees year by year except for 1938. This, being the year immediately following the transplanting of trees in the orchard, was associated with considerable set back in growth in case of all the rootstocks [Lal Singh and Sham Singh 1942]. Even in 1941—the first year of fruit bearing—there had been a tendency in case of rootstocks associated with vigorous growing trees (" Kharna Khatta ", Rough lemon and Shaddock) to register slightly increased rate of growth as compared with dwarfing rootstocks (Sweet lime and Citron). This slight increase in the rate of growth over the previous year in case of rootstocks associated with vigorous growing trees probably accounts for their tendency to commence bearing later than those in the dwarfing group. From 1942 onwards, fruit production is much on the increase year by year for each scion-stock combination except in case of citron during 1942 whereas there had been a corresponding set back in growth in each case except in case of citron during the same year (1942). These observations lead us to the

irresistible conclusion that increase in fruit production is invariably accompanied by decrease in amount of growth made. Such an antoganism in growth and fruitfulness has been previously recorded in case of mango by Lal Singh and Khan, A.A. [1939]. Hatton [1935] reached a similar conclusion when he said that the fall in the increment of cross-section year by year is accentuated with increased cropping. To illustrate this relationship more vividly in the present case, the mean yearly increase in girth and yield in all cases have been expressed in percentages, keeping growth and yield of trees on " Kharna Khatta " for 1941 as the basis. The percentage figures so calculated are compiled in Table VI.

TABLE VI

The relative performance of the Marsh Seedless trees on rootstocks raised from seed

Year of observation	Kharna Khatta		Rough lemon		Shaddock		Sweet lime		Citron	
	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield
1941	100	100	99	36	94	44	56	88	33	64
1942	83	232	90	168	83	184	43	144	38	56
1943	64	876	72	564	67	476	27	172	23	116
1944	38	1452	52	1052	44	956	21	312	18	196

The data in Table VI show that with " Kharna Khatta " as the rootstocks, the yearly growth increment of the Marsh Seedless trees has gone down by 62 per cent in four years as compared to the increase in fruit yield by 1452 per cent. In case of Rough lemon rootstock, the mean growth increment fell down by 47 per cent only and the production increased by 1052 per cent; in case of Shaddock the amount of growth fell down by 50 per cent with a corresponding increase in production by 956 per cent; in case of Sweet lime the annual mean growth decreased by 35 per cent with an increase in cropping by 312 per cent and in case of Citron the fall in growth increment amounted to 15 per cent only with a corresponding increase in fruitfulness to the extent of 196 per cent. It may perhaps be appropriate to further reduce these figures on a common level to facilitate comparison with a view to study the efficiency of various rootstocks under trial. Thus for every 1 per cent decrease in growth increment of grapefruit trees on " Kharna Khatta ", Rough lemon, Shaddock, Sweet lime and Citron, the corresponding increase in fruit production is 23 per cent, 22 per cent, 19 per cent, 9 per cent and 13 per cent respectively. This again shows the superiority of rootstocks associated with vigorous growing trees over those in the dwarfing group. The efficiency of various rootstocks under trial in respect of growth and cropping, therefore, may be put in the descending order as : " Kharna Khatta ", Rough lemon, Shaddock, Citron and Sweet lime. Yet, the last mentioned rootstock has been and still continues to be the popular rootstock with some nursery-men and quite a lot of prospective growers, for reasons previously mentioned by Lal Singh and Sham Singh [1942], ask for nursery trees budded on Sweet lime.

(C) The Statistical treatment of data given in Table V

(i) Correlation between growth increment and cropping

To study the relationship between increment in girth and the number of fruits borne in case of different scion-stock combinations in any one season, the values of correlation coefficients were worked out after eliminating differences due to blocks.

The figures thus obtained are set out in Table VII.

TABLE VII

Correlation coefficient between growth increment and fruit production in a particular year pertaining to various rootstocks under trial

Name of rootstock	No. of pairs examined	Degrees of freedom	Correlation coefficient	Expected value of correlation coefficient for P=.05
"Kharna Khatta"	24	14	—0·04	0·497
Rough lemon			—0·188	
Shaddock			—0·308	
Sweet lime			+0·254	
Citron			+0·137	

The above figures display a complete lack of correlation between the growth made and fruit produced in a particular year. In other words, irrespective of the rootstocks under trial, the growth and cropping appear to be quite independent of each other. On the contrary, the data in Table V clearly show that in case of all the scion-stock combinations under trial, the increase in cropping is associated with a corresponding decrease in amount of growth made. Therefore, the values of correlation coefficient between both the aspects of production were worked out as obtaining between the entire period of four years and in case of all the scion-stock combinations with results as given in Table VIII.

TABLE VIII

Correlation coefficient between growth increment and fruit yield in case of the Marsh Seedless trees for the four-year period from 1940-41 to 1943-44.

Rootstock	No of pairs examined	Degrees of freedom	Correlation coefficient	Expected value of correlation coefficient for P = .05
"Kharna Khatta"			—0·965	
Rough lemon	24	17	—0·952	0·456
Shaddock			—0·961	
Sweet lime			—0·770	
Citron			—0·510	

The negative correlations establish the view that increase in fruit production is accompanied by decrease in growth rate. This holds good for all the rootstocks under trial. The correlations are very high and almost perfect in case of "Kharna Khatta", Rough lemon and Shaddock. In case of the remaining two rootstocks, *viz.*, Sweet lime and Citron the correlations between growth increment and yield are not very high but are significant just the same.

It may be recalled (Table II) that the Marsh Seedless trees on "Kharna Khatta" are no longer associated with greatest vigour as was the case when they were in the vegetative phase, but in respect of cropping they are definitely far superior to those on the remaining rootstocks. Thus trees on Rough lemon now lead the rest in respect of tree size. Since with the commencement of bearing, the growth increment has fallen in case of each rootstock treatment, the question arises as to how an unit decrease in growth would be ultimately reflected in increased cropping. This point is best brought out by calculating the regression co-efficients for various scion-stock combinations under trial. The figures obtained are set out in Table IX.

TABLE IX

Regression coefficient in growth increment and yield of the Marsh Seedless trees for the period 1940-41 to 1943-44

Rootstock	Regression coefficient
"Kharna Khatta"	—66
Rough lemon	—59
Shaddock	—49
Sweet lime	—14
Citron	—11

The figures in Table IX show that the performance of the Marsh Seedless trees on "Kharna Khatta" rootstock remained outstanding for the first four years of fruit production. The trees on this rootstock are associated with maximum production for an unit decrease in growth rate. The next in order of merit are the trees on Rough lemon rootstock followed by those on Shaddock. The trees on Sweet lime and Citron have not only hopelessly fallen behind in tree size (Table II) but the crops produced in both cases have also been poor and uneconomic. Obviously this state of affairs has not merely been due to the smaller size of grapefruit trees on these two rootstocks but, as the regression coefficient values show, the trees on both these rootstocks are characterised by a low productive potential set up within them. In view of these considerations the unsuitability of sweet lime and citron as rootstocks for the Marsh Seedless grapefruit scion has been established within a short period of eight years after planting.

SUMMARY

1. The influence of certain rootstocks, propagated both from seeds and cuttings, on tree vigour and cropping of the Marsh Seedless grapefruit trees has been studied for a period of four years.

2. So far as tree size is concerned, the Marsh Seedless trees on rootstocks raised from seed have not been able to catch up with the corresponding trees on rootstocks raised from cuttings. The same generally holds good in respect of cropping as well except in one solitary instance out of sixteen comparisons when trees on "seedling rootstocks" outyielded those on "cutting rootstocks". The increased production in case of trees on "cutting rootstocks", however, appears to be of a transitary nature in view of their decreased rate of fruit production since 1943.

3. It has been shown that for every 1 per cent decrease in growth increment of grapefruit trees on "Kharna Khatta", Rough lemon, Shaddock, Sweet lime and Citron, the corresponding increase in fruit production is 23 per cent, 22 per cent, 19 per cent, 9 per cent and 13 per cent, respectively. This shows the superiority of rootstocks associated with vigorous growing trees over those in the dwarfing group.

4. A very high negative correlation existed between growth increment and cropping in case of each scion-stock combination under trial. Therefore, for every increase in fruit production, there was a uniform tendency in each case to decreased rate of vegetative growth reflected in ever decreasing progress in tree-size.

5. The trees on "Kharna Khatta" rootstock are associated with consistently higher fruit production for the entire period of four years as compared with the remaining rootstocks under trial. The results are very highly significant. What is equally important and significant is that this remarkable behaviour of increased fruit production of trees with "Kharna Khatta" as the rootstock, has been attained at the expense of comparatively least decrease in growth rate as shown by the regression coefficients worked out for each scion-stock combination under trial.

6. In view of both tree vigour and cropping, "Kharna Khatta" gave outstandingly the best result as compared to the remaining rootstocks under trial, rough lemon and shaddock coming

7. The trees on Sweet lime and Citron have not only hopelessly fallen behind in tree size but the crops produced in both cases have also been significantly poor. The unsuitability of both these rootstocks for the Marsh Seedless scion has, therefore, been established within a short period of eight years of the life of these trees.

ACKNOWLEDGMENT

The authors are indebted to Sirdar Bahadur Lal Singh, Fruit Specialist, Punjab, now Fruit Development Adviser to the Government of India, for his interest and encouragement throughout the course of these investigations. The Financial Assistance from the Indian Council of Agricultural Research for the carrying out of these investigations is also gratefully acknowledged.

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STUDIES IN HIBISCUS ESCULENTUS (Ladys' finger)

I. CHROMOSOME AND POLLINATION STUDIES

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(With two Plates)

According to Sturtevant [Hedrick, 1919] ladys' finger, gumbo or okra has its origin in tropical Africa. It was known to the Spanish Moors and was used by the Egyptians in the 12th or 13th century. Schweinfurth [1874] found the plant growing perfectly wild on the White Nile. According to *Flora of British India* ladys' finger was also probably originally wild in India as well. De Condolle [1904] however says, 'This opinion seems erroneous, as there is no mention about it in the old Sanskrit literature'.

Ladys' finger or okra is a warm season crop and is grown extensively throughout India. In the Punjab it is one of the most important summer vegetable crops and covers about 1/10 of the area annually put under summer vegetables. According to Purewal [1944] in the Punjab plains two sowings, one early and the other late, are made in a year. For early crop the seed is sown from middle of February to middle of April and for the second or late crop in July. In the Punjab hills the best time to sow okra seed is about the middle of May. Okra seed germinates best at about 85°F. and does not germinate at soil temperature below 68°F., therefore, for early sowings, when the soil temperature is low, seed is sown thickly at the rate of 16 to 24 lb. per acre. When the soil is warm seed should be sown at the rate of 8 to 10 lb. per acre. Okra is sown on ridges 2½ to 3 ft. apart depending on the variety, the dwarf sorts being spaced closer. The seed is sown thickly about ½ in. deep on top of the ridge in hills, one foot apart, and when the plants are well established they are thinned to one plant in each hill.

From the dietetic point of view leafy vegetables such as spinach, lettuce, cabbage are the most important but according to Purewal [1944] okra pods in the immature edible stage are also a rich source of vitamins A and B and mineral elements like calcium, phosphorus and iron. It is an excellent source of iodine so useful for the control of goiter. The fresh fruit analysis yields about 80 per cent water, 4 per cent protein, 0·4 per cent fat, 12 per cent Nitrogen Free Extract, 1·4 per cent fibre and 1·5 per cent ash.

The okra crop has got a wide usage. In the Punjab the *okra* fruit is mainly used as a cooked vegetable; the mature pod and stem containing fibre are utilized in the paper industry; the plant as a whole is soaked in water and the resulting solution is used as clarifier in the manufacture of *gurh*; and stem and leaves are also used in compost making.

In America okra is used in soups and various culinary preparations in which meats form an important part. Woodroof [1927] states that it is frequently employed for feeding dairy cattle, since there is always an accumulation of unmarketable green pods. He carried out an experiment on feeding okra pods to two Guernsey cows, resulting in an increased yield of milk.

In Africa the use of okra fruit as a vegetable is scarcely known, but it is cultivated rather extensively to provide a substitute drink for coffee. The seeds of the ripened fruit are dried and roasted brown in a covered clay pot to prevent the popping or bursting of the kernels. Then the roasted kernels are ground to a fine powder. The odour of the powder is strongly suggestive of coffee. The drink is prepared like coffee except that the amount of powder used is usually doubled.

Halverson and Naiman [1926] analysed the oil from okra seed and found that mature seeds possess good feeding value in that they consist of 25 per cent protein and 20 per cent oil. This plant being a prolific and vigorous grower in the cotton belt has possibilities of economic importance due to its high oil content and to the feeding value for animals of the high protein meal after the oil is extracted. The composition of okra seed is comparable to cotton seed.

Okra is said to possess considerable medicinal properties. Melegod [1924] thus writes, 'Okra is a well known vegetable cultivated throughout the island (West Indies) but its excellent properties as a nutritious vegetable possessing considerable medicinal properties has been little realized. The fruits in their unripe state are much esteemed as a vegetable and are prepared in various ways. These abound in mild mucilage possessing valuable emollient and demolucent properties and is used in case of catarrhal affection, fevers, irritable state of bladder, etc. In hoarseness and dry irritable state of the throat causing troublesome cough, a soup prepared by boiling down a few unripe *bandakka* (okra pods) in about a pint and half of water and taken after straining and sweetening to taste has proved beneficial in the case of writer. Sometimes a free inhalation of the vapour of this hot *bandakka* soup has been known to act wonderfully on dry troublesome cough and hoarseness. In case where there is difficulty in passing urine, the *bandakka* soup has acted very beneficially. The leaves of *bandakka* plant are used externally as an emollient poultice'.

In accordance with the importance of the crop in the tropical countries of the world, little research work on the classification, culture and breeding of the crop has so far been done. In the U. S. A. Woodroof [1927], Beattie [1918] and Jones and Rosa [1927] have studied the general characteristics of the plant and its cultural requirements. Owen [1910] has conducted some studies on the development of the fruit in the okra plant. Miller [1937] has submitted a preliminary report on okra breeding in Lousiana. In India practically no improvement work has so far been done on this crop. Therefore the studies reported below were made as a preliminary to starting intensive genetical and breeding work.

Chromosome studies

Krenke [1929] reported the haploid chromosome number in okra to be 59,60 or 61. It was, therefore, deemed desirable to ascertain the exact number of chromosomes in this plant.

Three days after protrusion of seedlings at 8 a.m. the root tips were fixed for 24 hours in Navashins fluid to which maltose was added. The air was exhausted by means of an exhaust pump; after fixation the material was washed in tepid water for three hours. The material was embedded by the usual paraffin method. The sections were cut 10μ thick and stained in Iodine Gentian violet, as suggested by De La Cour [1931].

The fixation and staining was found to be satisfactory by this method but when the slides were kept in iodine-iodide for two minutes, the chromosomes in this particular case were found to be destained. The keeping of the slides in iodine-iodide for 30 seconds, however, obviated this defect and gave satisfactory results.

The chromosome counts of all the four varieties i.e. B.1, B.12, B.15, B.19 were made and the number ($2n$) was found to be 120 in each case. The diagrams of the chromosomes of two varieties were drawn with the help of camera lucida at the bench level with x 4300 magnification. The figures drawn (Plate III, figs. 1 and 2) indicate that though there is no difference in the number of chromosomes but there are well marked morphological differences in the chromosomes of these varieties.

Pollination studies

Ladies' finger (*Hibiscus esculentus*) belongs to the natural order Malvaceae. The members of this natural order belong to the group of plants regarded as often cross-pollinated. But so far the floral mechanism and mode of pollination of this plant has not been completely reported, nor any data on the extent of cross and self-pollination are available. Hence these studies together with observations on time of opening of flowers, anther dehiscence, pollen germination, receptivity of stigma, pollen tube growth and development of fruit were undertaken.

Materials and methods

The okra variety B.1 which is one of the most promising strains was selected for pollination studies but for determining the extent of natural crossing, two more varieties, viz. B.14 and B.19 were also grown side by side with B.1. The latter two varieties exhibit contrasting character differences from those of variety B.1 in earliness and shape of fruit, and as such the natural hybrids resulting from these varieties could be singled out with ease in the F1 generation.

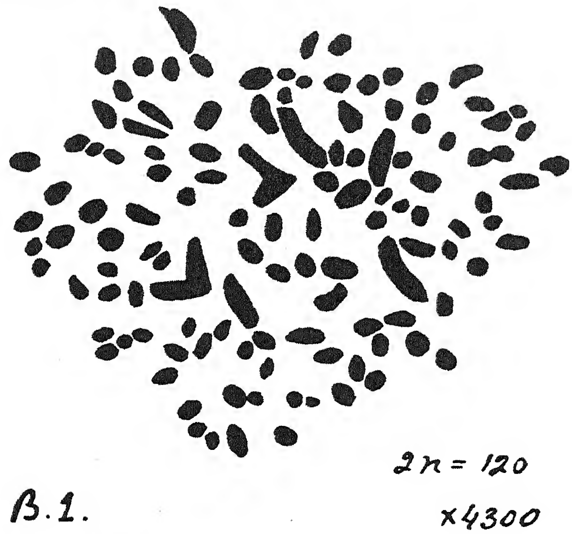

FIG. 1.
Showing the chromosomes in B. 1.

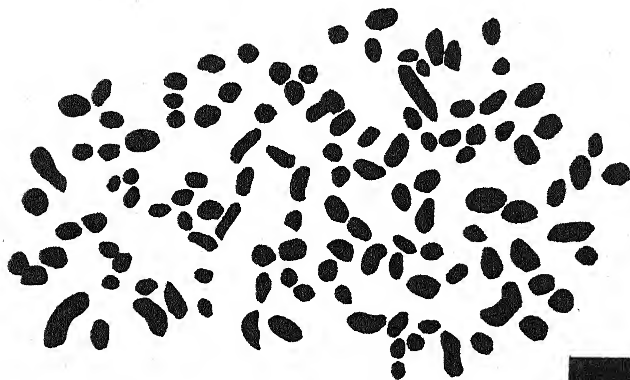

FIG. 2.
Showing the chromosomes in B. 12

FIG. 3(a)
Flower of Okra

FIG. 3(b).
Showing the opening of 3 flowers on a single stem

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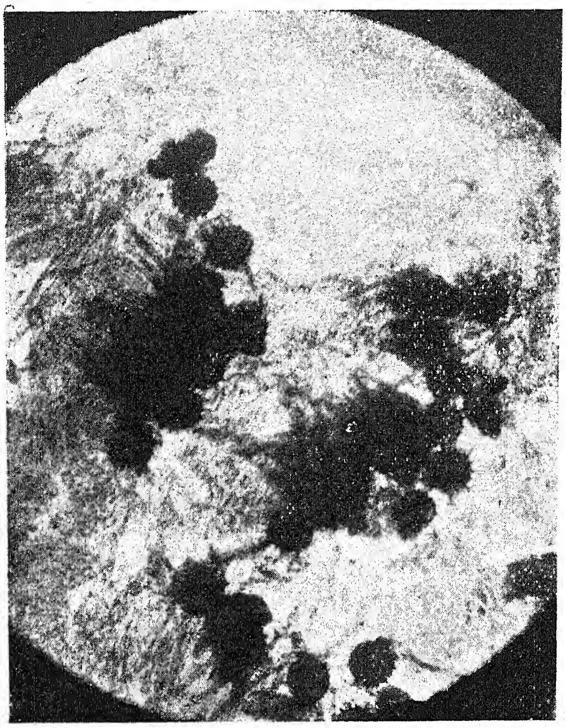

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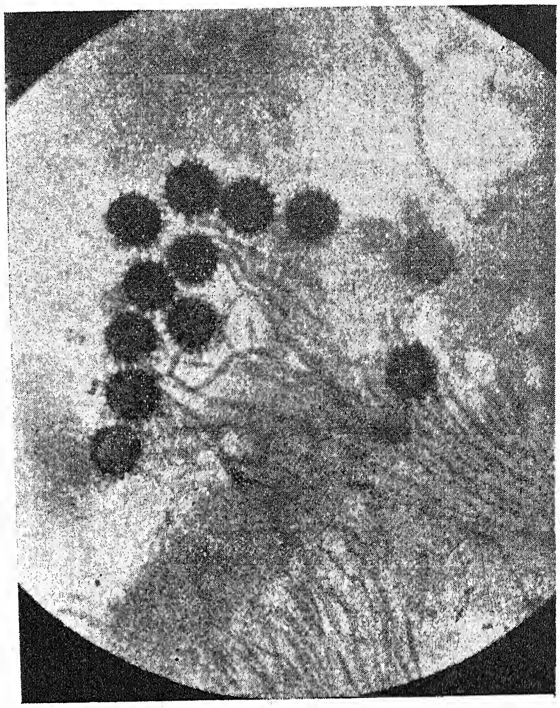
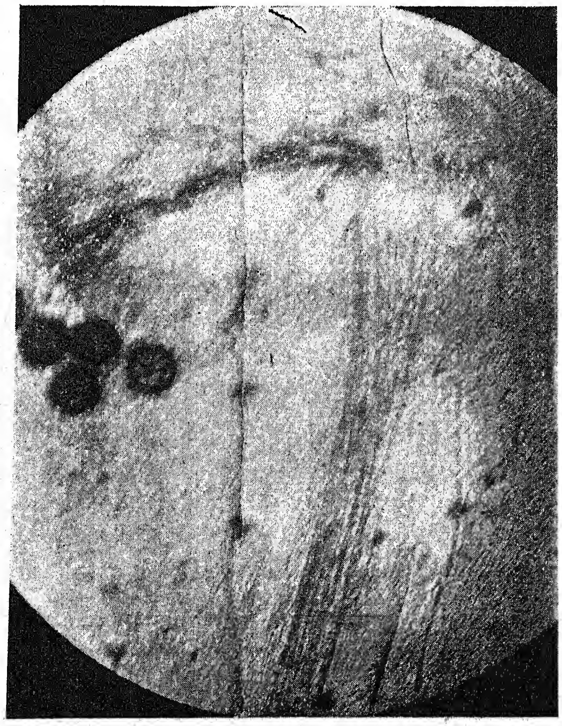


B



C

FIG. 1.

Showing the germination of pollen on stigmatic surface

A—After 5 minutes.

B—After 15 minutes (The tubes have grown sufficiently long)

C—After 30 minutes (Tubes are seen bending towards the styler tract)

Observations and experimental results

Structure of the flower

The flower of the okra plant arises in the axil of the 6th to 12th leaf and upwards depending upon the early or late flowering of the variety. The flowers are hermaphrodite, large and bright yellow in colour.

Calyx. The exterior calyx has from 8-12 linear, caducous bracteoles. The interior calyx spathiform, circumscissile 5-7 fid, not falling off till after the flower opens.

Corolla. Petals five, bright yellow with a crimson centre, connate at the base with the stamina tube.

Androecium. Staminal tube truncate, five toothed at the summit, filaments numerous, anthers reniform, one celled.

Gynaeceum. Ovary multilocular (5-7 celled) each with 3 or more loculicidal ovules. Styles 5, connate below, stigma capitate or subspathulate.

Time of opening of flowers

A flower bud appears in the axil of each leaf above the sixth or eighth leaf depending on the variety. The crown of the stem at this time bears 3-4 undeveloped flowers but later on during the period of profuse flowering of the plant there may be as many as ten undeveloped flowers in a single crown. As the stem elongates, the lower most flower buds open into flowers. Woodroof [1927] stated, ' There may be a period of two, three or more days between the time of development of each flower, but never does more than one flower appear on a single stem'. The observations made by the authors under field conditions, however are not in accordance with those of Woodroof as in a number of cases individual stems were observed to bear two or even three open flowers on the same day. This phenomenon is very well illustrated in Plate III, fig. 3 (*b*).

For determining the proper stage at which the buds open into flowers, 50 buds were selected at random and labelled in the evening at 6·30 p.m. General observtions regarding the colour of the buds and their toughness to slight compression with finger tips were recorded. Physical measurements of the buds such as diameter and length were also taken. On an examination of the selected buds the next morning at 8·30 a.m. it was found that only whitish green, easily compressible buds measuring about $2{\cdot}82 \times 1{\cdot}55$ cm. opened into bright yellow flowers.

For recording the time of opening of flowers 50 buds which were likely to open the next morning were selected on 14-7-43 at 6·30 p.m. and labelled. Observations were recorded in the morning on 15-7-43 as given in Table I.

Table I

The time of opening of flowers on 15-7-43

No. of flowers observed	Time of opening			
	8·20 to 8·25	8·25 to 8·30	8·30 to 8·35	8·35 to 8·40
50	8	25	14	3

From the above data it is seen that all the buds opened into flowers between 8·20 to 8·40 a.m. on a bright sunny day. On cloudy and cold days, however, they opened very late. It was also seen that flowers remain fully open till noon, withering and collapsing towards the sunset.

Mode of opening of flowers

For this purpose ten pale coloured buds likely to open the next morning were closely observed during the night. These observations revealed that around mid-night the covering of the calyx ruptured from one side and corolla lobes enclosing other floral organs protruded. At 5 a.m. the corolla tube had come out altogether leaving the calyx at the base. The petals distended slowly with the rising of the sun and were fully expanded at about 8·30 a.m.

Dehiscence of anthers

The stamens are indefinite, monadelphous with kidney shaped anthers which are dorsifixed to the filaments. The dehiscence of the anthers is transverse and starts 15 to 20 minutes after the opening of the flower. All the anthers of a single flower do not dehisce at the same time but dehiscence starts from the topmost downwards, taking in all 5-10 minutes to complete the process.

Pollen

The pollen grains are large, spherical and frequently adhering owing to the presence of a mucilagenous substance on the surface bright yellow with thick granular exine provided with numerous large, long, conical spines (Plate IV, fig. 1). They varied in size from 672·82μ to 848·48μ with different varieties which in turn exhibited marked differences in the size of the flower, leaf shape, leaf size, stem height, etc.

Germination of pollen in-vitro

A number of experiments were carried out in connection with the germination of pollen of okra *in-vitro.* When okra pollen was placed in moist atmosphere at room temperature it gave only 8·6 per cent germination and on 1 per cent agar plus 55 per cent sugar medium 18 per cent. But the highest and most successful germination was obtained when the extract of stigmatic and stylar tissues was added to the sugar—agar medium as given below.

Medium A—1 per cent agar plus 55 per cent sucrose

Medium B—1 per cent agar plus 55 per cent sucrose plus extract of stigmatic and stylar tissue

TABLE II

The germination of pollen grains in A and B media at room temperature

Treatment No.	No. of grains in each case	Percentage germination	
		Media A	Media B
1	100	14	23
2	100	20	32
3	100	17	29
Average	100	17	28

The figures given in the Table II show a mean increase of 11 per cent in the germination of pollen as a result of the addition of the extracts from stigmatic and stylar tissue. It was also noted that the germination in agar plus sugar medium started earlier and the pollen tubes grew more rapidly than in moist conditions. Some of the pollen grains gave out as many as six pollen tubes, one of the tubes being longer than the remaining ones. Some branching pollen tubes were also noticed while studying the germination of pollen both on stigmatic surface and in artificial media. It may be concluded from the above results that every pore of the pollen grain is a potential germ pore.

Germination of pollen on stigmatic surface. The main object of this study was to determine the probable length of time which the pollen takes to germinate on stigmatic surface. The method of staining smears of stigma in aceto-carmine, as suggested by Anderson and Sax [1934] was tried in the first instance, but was found to be unsatisfactory as the pollen tubes could not be easily differentiated from the papilliate cells of the stigma. The method suggested by Iyengar [1939] was then followed with successful results.

Those okra buds which were due to open in the morning were emasculated the previous evening. In the morning they were hand pollinated and the flowers were then collected after an interval of 5, 15, 30 and 45 minutes. The stigmas were placed in 1 per cent aqueous magenta and after three hours they were transferred to lactic acid and were left there over-night. On the following day, the material was mounted on the slide in a drop of fresh lactic acid. A thick cover glass was placed on it pressing it gently for the purpose of spreading. The examination of the slide under the microscope showed pollen tubes emerging out of the pollen grains. The pollen tubes were quite distinct on account of their purple colour as against light red colour or colourlessness of the rest of the tissue (Plate IV, fig. 1). It appeared that the pollen grains germinated within five minutes after their deposition on the stigma. A further study was made by treating the flowers in the above fashion and collecting the stigmas 2, 3, 4 and 5 minutes after pollination, which showed that pollen grains started germination only about five minutes after their deposition on the stigma.

Pollen tube growth. This study was made to determine the time taken by the pollen tube to traverse the stylar region, in other words, the interval between pollination and fertilization. For this purpose the following experiment was conducted to determine the rate of the pollen tube growth.

A large number of flowers was pollinated with hand at about 8·45 a.m. which is the usual time of dehiscence, and after the uccessive intervals of each hour, the styles were excised close to the ovary in order to find out whether the pollen tubes (with the generative nuclei) had traversed the stylar length during any particular interval. The results obtained are given in Table III.

TABLE III

The percentage of fruits set by excising the style at different intervals after pollination

Treatment No.	No. of flowers	Time interval after which the style is excised (hours)	Percentage of fruit set
1	100	1	*nil*
2	100	2	23
3	100	3	52
4	100	4	72
5	100	5	83
6	100	6	96

From the above data it is clear that the most actively growing tubes reached the ovule two hours after pollination, while three hours after pollination the percentage of fruit setting increased to 52 per cent indicating a proportionately greater number of pollen tubes traversing the stylar region. At 3 p.m., i.e. six hours after pollination the maximum number of tubes must have reached the ovules as the excision of the style did not have any effect on setting of the fruit. These results show that the time elapsing between pollination and fertilization in okra is very short. Considering 8-45 a.m. as the optimum time of pollination, the first few tubes reached the ovule two hours after pollination and in less than six hours fertilization was complete in all the flowers.

Stigmatic receptivity

The flowers of okra plant remain open for a few hours only. After pollination in the morning, the petals begin to shrival at about noon and late in the afternoon the flowers are turned into a withered, twisted and dying mass. By the following morning these flowers wither, fall off or remain

at the tip of the developing fruit. In order to find out the proper stage of stigmatic receptivity, which could either be before the opening of flowers or after the flowers had opened, premature flowers were bud pollinated in the following manner :

Buds that were to open 24 hours later were emasculated by removing carefully by pointed forceps the sepals, petals and stamens. The stigma at this stage was dull red in colour as against the bright coloured stigma of the fully open flowers. Mature pollen grains of the same variety were then dusted on the stigmatic surface. The pollinated flowers were covered with paper bags which were removed after two days in order to expose the fruit to sun light and to record the percentage of shedding or setting of the fruit as the case may be. The observations recorded showed that no fruit had set, indicating that stigma was not in a receptive condition at least 20 hours before the opening of the flower. It may be argued that the failure of the fruits to set might be due to the injury incidental to emasculation especially when the buds were in such a young stage, i.e. 24 hours before opening of the flower or it may be said that the pollen might have failed to germinate. The chance of 100 per cent failure due to injury are altogether precluded as the buds and floral parts 24 hours before opening of the flower are fairly large to be handled with ease to avoid any injury to the stigma. The lack of setting cannot also be due to the failure of the pollen as the data in Table III clearly show that pollen is viable for at least four hours after dehiscence and probably for a longer interval. Thus, the failure in setting the fruit was actually due to unreceptivity of the stigma.

In the second case the fully open, bright coloured flowers with velvety stigma were pollinated with fresh pollen. This operation resulted in the normal setting of the fruit, showing that the stigma was in a receptive condition as soon as the flowers opened fully.

Pollination

In order to study the mode of pollination the following experiments were carried out :—

1. *Open pollination.* Fifty flowers were tagged for identification and were allowed to pollinate and develop under natural conditions. The setting of the fruit was cent per cent.

2. *Self Pollination (by bagging of the flowers).* Fifty flowers were covered with paper bags a day before opening to avoid the effect of external agencies like wind and insects in the transference of pollen. The bags were removed the next day after the flowers had shrivelled. The setting of the fruit was cent per cent.

3. *Self pollination (by hand under bag).* The buds which were expected to open the following morning were bagged in the evening. Next morning out of the bagged buds fifty flowers were labelled and pollinated with brush to ensure proper pollination. The bags were then put on again and removed the next day so that the fruit may develop normally. The setting of the fruit was only 98 per cent.

In the first two treatments the setting of the fruit was cent per cent but in the third case the setting was 98 per cent, showing that there is no significant difference in the percentage of fruit set which means that okra is potentially a self-fertilized crop.

Although the okra flower is mostly self-pollinated but the possibility of cross pollination cannot be ruled out in view of the fact that okra flowers are frequently visited by insects. Our observations showed that honey bees and black ants are the most common visitors. Beattie [1918] stated, 'The common bumble bee is frequent visitor of the flowers of okra, and a single bee one morning was observed to pollinate over 500 flowers, comprising more than 50 samples. In this instance practically every flower in the field was visited and pollinated although no pollen had previously been transferred.' In view of the indefiniteness of the previous writers on the percentage of natural crossings the authors undertook to determine it under natural conditions, by planting varieties B.1, B.14 and B.19 side by side in four replications. These varieties have contrasting characters which could be detected in case of hybrids resulting from them. The seed was collected from open pollinated flowers and sown during the next season. The number of natural hybrids was counted.

TABLE IV

The natural hybrids in different varieties sown adjacent to one another

No.	Variety	Total No. of plants	Hybrids	Percentage of natural crossing
1	B.1	144	14	9·7
2	B.9	130	7	5·4
3	B.14	144	10	7·0
4	B.1	120	5	4·0
5	B.9	140	9	6·4
6	B.14	140	8	5·7
7	B.1	144	10	7·0
8	B.9	144	27	18·75
9	B.14	132	15	11·4
10	B.1	135	13	9·4
11	B.9	144	12	8·3
12	B.14	140	15	10·7
	Total	1,657	145	*Average* 8·75

Table IV shows that natural cross pollination in different plots varied from 4·0 to 18·75 per cent with an average of 8·75 per cent. But there was no significant variation in the percentage of cross pollination in different varieties when plots under each variety were taken collectively. In varieties B.1 and B.14 the percentage of natural crossing was 7·5 and 8·7 respectively.

Development of Fruit

The present investigation was carried out for determining the rate of growth at various stages of development during the growing period and also to ascertain the diurnal effect on the development of okra fruit. It is natural that rate of development would vary in accordance with the prevailing temperatures but the growth increment will remain constant. These determinations were made during the month of June from 16-6-1943 to 29-6-1943 when the hottest weather prevails at Lyallpur.

Forty-five flowers were labelled bearing the date on the day of their opening so that they might be easily distinguished from other fruits and in order to keep a record of their age. The pod length was measured by a meter rod and the pod girth by means of a pair of callipers twice a day at 7-8 a.m. and 6-7 p.m. Similar measurements were also made of the length of the stalks and diameters of the receptacles, until the growth of the fruit ceased.

The measurements recorded showed that the pod obtained its full length 15 days after the opening of the flower. The length of the fruit stalk increased from 1·06 cm. to 2·72 cm., i.e. 2·5 times its original length and the diameter of the receptacle from 1·02 cm. to 2·19 cm., that is, it was nearly doubled in thickness. The examination of the data showed that the pod increased in length at a slow but progressive rate for the first five days and then at a very quick pace for the next two days and afterwards again at a degressive slow rate for the next eight days till the fruit ceased to grow any more. Thus the fruit increased from 0·97 cm. to 15·4 cm. in 15 days. The diameter of the pod increased from 0·69 cm. to 2·29 cm., i.e. about thrice its original diameter at the opening of the flower.

Diurnal effects on the development of fruit. Measurements were taken between 7-8 a.m. and 6-7 p.m. daily comparing the increase in length of the fruit as affected by day and night. The data invariably showed a higher rate of growth at night than during the day. Culpepper and Moon [1941] stated that the rate of growth of okra pod was somewhat more than doubled for each 18°F. (10°C.) rise in temperature at probably all stages of development. But in the present case it was observed that though the temperature at night was lower by 30°F. than that of the day the fruit increased in length more during night than during day. The probable reason that could be assigned to this was that the cells were fully turgid during night on account of comparatively less loss of water through transpiration. Consequently growth of the fruit was more active during the night than in the day.

Time of picking. The observations made on the development of fruit further revealed that the fruit was very small and tender when it was five days old (5·8 cm.). But during the next two days the fruit made a remarkable development (11·3 cm.) while the quality as regards tenderness and colour was not much affected. The above fact indicates that the fruit in this case should be picked when it is 6-7 days old. At that stage of development the quality of fruit is not impaired whereas the yield obtained is nearly double than that of the five day old fruits.

Summary

The Chromosome counts made from the root tips of four varieties of ladys' finger (*Hibiscus esculentus*) showed that 2 *n* number was equal to 120 in each of them.

The flowers of the okra plant usually opened at about 8-20 to 8-45 a.m. The pollen is shed about 10 to 15 minutes after the opening of the flowers and it takes another five to ten minutes for all the anthers of a single flower to dehisce.

The pollen grains are bright yellow, large, spherical with thick conical spines which are round at the base and tapering at the end. The pollen grains usually adhere together on account of the secretion of an oily substance from the exine.

The pollen grains were successfully germinated in an artificial medium of 1 per cent agar plus 55 per cent sucrose at room temperature. The germination started 30 minutes after the pollen grains were placed on the media.

The pollen grains germinated on the stigmatic surface five minutes after their deposition on stigmatic surface.

The stigma is receptive as soon as the flower opens, but, at least 20 hours before opening, the stigma was found to be unreceptive.

The percentage of fruit setting two hours after pollination was 23 while after three hours it was 52 and after six hours it increased to 96 showing thereby that the time lapsing between pollination and fertilization in okra is very short.

The incidence of natural crossing in okra was found to vary from 4·0 to 18·75 per cent, the average being 8·75 per cent.

The pod completed its growth in 15 days and the best time for picking was determined to be 6-7 days after the opening of the flower.

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DISCOVERY OF THE UREDO-STAGE CONNECTED WITH THE AECIDIA SO COMMONLY FOUND ON SPECIES OF *BERBERIS* IN THE SIMLA HILLS

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(With four Plates)

The occurrence of aecidia on *Berberis* was first recorded in this country by Barclay [1887]. Later Butler [1905, 1] remarked that the Mussoorie and Jaunsar barberries bear an aecidium entirely different from that found near Simla. He [Butler, 1905, 2] also stated that 'Around Simla *Aecidium Berberidis* undoubtedly occurs on *B. lycium*, and probably also on *B. coriaria* Royle, *B. aristata* D.C., and a species which has been doubtfully referred to *B. umbellata* Wall. It probably also occurs on *B. vulgaris* to the west of Simla, where alone this species is found'. On account of extreme rarity of black rust on wheat and barley in the neighbourhood of infected barberries, he concluded that the aecidium, referred to above, was not allied to black rust of cereals and probably belonged to some other specialized form of the parasite.

East of Simla, Butler identified another interesting species on *B. coriaria*, *B. aristata* and *B. lycium*. It was distinguished from the former by the peculiar deformity of the affected branches and the formation of witch's-broom. The aecidiospores of this species failed to infect cereals and the urenial host remains unknown. Butler, therefore, named the species as *Aecidium montanum*.

Butler and Hayman [1906], Butler and Bisby [1931], Arthur and Cummins (1933), Sydow and Mitter [1935] and Mundkur [1938] also reported the presence of *Aecidium berberidis* on different species of *Berberis* but there is no evidence supported by experimental data to connect it with black rust of cereals or of any of the grasses.

Butler [1918] observed that the barberry aecidiospores in Kumaon could not be got to infect wheat and probably belonged to some other race of the parasite. This was supported by Mehta [1929, 1931 and 1933] who stated that inoculations made on wheat and barley seedlings with aecidiospores from barberries found in the hills gave negative results. Later, he [Mehta, 1940] stated that 'typical aecidia of *Puccinia graminis* have not been found during these studies' and only in the case of *B. lycium*, a specimen collected in May, 1933, was provisionally identified by Butler as belonging to *P. graminis*. The specimen, as stated by Butler, did not quite agree with the European material of *A. berberidis* Gmel., the aecidial stage of *P. graminis* Pers. Other specimens sent to him were identified as belonging to *Aecidium montanum*.

The uredo and teleuto hosts of *Aecidium montanum* remain undiscovered and nothing was known till 1940 of such hosts for the other kind of aecidia that are so commonly found on indigenous species of *Berberis* in the hills of India, one collection of which was provisionally identified by Butler as belonging to *P. graminis*. Mehta [1933] reported that no infection took place on wheat and barley even as a result of inoculations with aecidiospores from the shorter aecidia occurring on *Berberis lycium* and *B. aristata*. As far as the writer can see the material referred to by Mehta belonged to the aecidial stage dealt with in this article.

During the course of investigations on cereal rusts, intensive search was made in the hills for the uredo-stage of the aecidium under reference and in September, 1940, the writer for the first time came across heavily infected plants of *Agropyron semicostatum* Nees growing near diseased bushes of *B. lycium* at Taradevi (altitude 5,000 ft., six miles west of Simla). This was very suggestive of a possible connection between the rust on *Agropyron* and the common aecidium on *B. lycium* recorded by earlier observers.

Extensive observations made in the Simla hills along with laboratory experiments have established this connection, leading to the identification of a new 'Specialized form' of *Puccinia graminis* Pers. Full details are supplied in this article.

It may be stated here that the occurrence of black rust on *Agropyron* is a new record for this country. In England, Europe and the U. S. A. *Agropyron repens* has been found to be infected by *P. graminis secalis* in nature [Stakman and Piemeisel, 1917 ; Mehta, 1923 ; Teterevnikova, 1927 ; Wright and Kirby, 1939]. According to Stakman and Piemeisel [1917] *Agropyron caninum*, *A. cristatum*, *A. smithii*, *A. spicatum* and *A. tenerum* are feund infected with *P. graminis tritici* in nature in the U. S. A., and *A. elongatum* is easily infected artificially with that rust while *A. repens* is weakly infected. Waterhouse [1929] observed that *P. graminis tritici* is present on A. *scabrum* throughout the year in Australia.

Methods of study

During the period of study, a large number of collections of infected *Agropyron* showing the uredo and teleuto-stages was made in the neighbourhood of Simla as well as from the higher altitudes of the Simla hills up to Narkunda (9,200 ft. a.s.l.). Teleutospores collected from different places were tested for germination under varying conditions and after different treatments.

Inoculations were made with sporidia on all the species of *Berberis* that are found in the Simla hills and also on (i) *Berberis tinctoria* Lesch. (from the Nilgiris), (ii) *B. umbellata* Wall. (from Darjeeling), (iii) *B. pseudumbellata* Parker (from Tangmarg, Kashmir) and (iv) *B. vulgaris* Linn. raised from seed received from England and the U. S. A., in order to test their susceptibility to the rust of *Agropyron*.

Inoculations with aecidiospores produced artificially on *Berberis* were made on seedlings of three indigenous species of *Agropyron* simultaneously with those of cereals (wheat, barley, rye and oats).

Repeated tests were carried out with the aecidial material occurring in nature on the various species of *Berberis* near Simla.

Morphological and physiological studies of the rust on *Agropyron* were also made including cross inoculations on some of the wild grasses and the cereals.

Germination of teleutospores

As stated above, the teleuto-material of the rust on *Agropyron semicostatum* was first found at Taradevi in September, 1940. There were no uredospores in any sorus at that time. More collections of teleutospores were made in December, 1940, from the same place. During that month infected stems of this grass were also noticed at village Sanahan in east Simla but, as at Taradevi, uredospores could not be found.

In the following year when Taravedi was visited on 29 June, 1941, the grass was free from rust but pycnia were visible on leaves of *Berberis lycium*. A month later bushes of *B. lycium* were found to bear aecidia and within ten feet of those bushes the grass was infected with the uredo-stage. By the end of September the rust on the grass had all passed into the teleuto-stage.

Again in 1942, there was no infection on plants of *Agropyron* on 25 June but pycnia had started appearing on bushes of *B. lycium*. A month later aecidia had been formed on *B. lycium* and the grass had traces of rust. Early in August infection was well-advanced on the grass and most of the stems were found heavily rusted.

In greenhouse cultures teleutospores were formed on infected leaves within two weeks of rust appearance which shows that the uredo-stage is of a very short duration. This was supported by field observations.

Detailed information regarding teleutospore collections made from time to time, their storage, tr atment and germination is given in Table I.

TABLE I

Detailed information regarding the collection of teleutospores from Agropyron semicostatum *Nees from different places from time to time, their storage, treatment and germination*

No.	Date and place of collection, its storage, etc.	Further treatment	Percentage germination	Remarks
1	From Taradevi on 15-9-40 and stored in :			
	(i) a room at Simla .	(*a*) Spores floated on tap water after soaking straw overnight	30	(*a*) Germination was tested in shadesoon after collection. Spores started germinating in 48 hours
	(ii) in refrigerator at 40-50° F.	(*b*) Spores floated on tap water after one wetting and drying, each for one day, followed by soaking straw overnight	60	(*b*) Germination was tested on 17-94-0 in shade. Spores started germinating in 48 hours
		(*c*) Straw dried and soaked several times	60—100	(*c*) Germination was tested several times during October, 1940, and July, 1941. Spores started germinating in 48 hours and in some cases in 6 hours
		(*d*) Straw dried and soaked several times	10	(*d*) Germination was tested in August, 1941
		(*e*) Straw soaked in water overnight	5	(*e*) Tested in September, 1941. Germination after 72 hours
		(*f*) Straw soaked in water overnight	None	(*f*) Germination was tested in October, 1941
2	From Taradevi on 29-6-41 ; formed in September-October, 1940 and exposed to natural conditions	(*a*) Straw soaked in water overnight	80	(*a*) Germination was tested soon after collection
		(*b*) Soaked in water overnight	90—100	(*b*) Germination was tested several times in July, 1941, at room temperature
3	From Sanahan on 15-12-40, and stored in a room at Simla	(*a*) Straw soaked in water overnight soon after collection	75	(*a*) Germination was tested soon after collection. Spores germinated in 24 hours
		(*b*) Straw soaked and dried several times	75—100	(*b*) Germination was tested several times during January-July, 1941. Spores germinated in 6 hours in some cases
		(*c*) Straw soaked and dried several times	10	(*c*) Germination was tested in August, 1941
		(*d*) Straw soaked in water overnight	None	(*d*) Tested in September, 1941
4	From Sanahan on 16-4-41. Formed in September-October, 1940 and exposed to natural conditions	Straw soaked in water overnight	90	Germination was tested soon after collection
5	The same as above, collected on 15-7-40	Straw soaked in water overnight	33	Tested soon after collection. Germination in 36 hours
6	From Taradevi on 23-7-41 ; just formed	Straw soaked in water overnight	Traces	Tested soon after collection. Germination in 5 days
7	From Taradevi on 9-9-41 ; stored in—			
	(i) a room at Simla .	(*a*) Straw soaked in water overnight	40	(*a*) Tested soon after collection. Germination in 48 hours
	(ii) refrigerator at 40-50° F.	(*b*) Straw dried and soaked several times alternately	50—100	(*b*) Tested several times during October, 1941 to May, 1942 ; Spores germinated in 6-48 hours
8	From Sanahan on 30-9-41 ; stored in—			
	(i) a room at Simla .	(*a*) Straw soaked in water overnight	33	(*a*) Tested soon after collection
	(ii) refrigerator at 40-50° F.	(*b*) Straw dried and soaked several times alternately	50—100	(*b*) Tested several times during October, 1941 to May, 1942. Spores germinated in 6-48 hours

No.	Date and place of collection, its storage, etc.	Further treatment	Percentage germination	Remarks
9	From Theog (alt. 7,500 ft.) on 4 October, 1941	Straw soaked in water overnight	50	Tested soon after collection. Spores germinated in 48 hours
10	From Mattiana (alt. 7,900 ft.) on 5-10-1941	Straw soaked in water overnight	60	Tested soon after collection. Spores germinated in 48 hours
11	From Narkunda (alt. 9,200 ft.) on 6-10-41	Straw soaked in water overnight	60	Tested soon after collection. Spores germinated in 48 hours
12	From Arki (alt. 3,000 ft.) on 15-12-41	Soaked in water overnight	·75	Tested soon after collection. Spores germinated in 24 hours
13	From Jaku (Simla) on 22-3-42.	(*a*) Straw soaked in water overnight	60	(*a*) Germination was tested soon after collection. Spores germinated in 48 hours
		(*b*) Straw soaked, dried and soaked in water for 24 hours, 24 hours and 3 hours, respectively	100	(*b*) Tested soon after collection. Spores germinated in 8 hours
14	From Taradevi on 15-4-42. Formed in the previous year and exposed to natural conditions	Straw soaked in water overnight	80	Tested soon after collection. Spores germinated in 24 hours
15	From Sanahan on 20-4-42. Formed in the previous year and exposed to natural conditions	Straw soaked in water overnight	90	Germination was tested soon after collection. Spores germinated in 24 hours
16	From Theog on 29-5-42 on previous year's straw	Straw soaked in water for 3 hours	70	Tested soon after collection. Spores germinated in 8-10 hours
17	From Mattiana on 30-5-42 on previous year's straw	Do. . . .	80	Do.
18	From Narkunda on 1-6-42. from previous year's straw	Do. . . .	70	Do.

Although teleutospores germinated soon after formation without any special treatment, better results were obtained as the material matured either by exposure to weather or by alternate drying and wetting to simulate natural conditions, as shown in Table I. Soon after their formation in July-September, the germination of teleutospores was from trace to 40 per cent rising gradually to 60-100 per cent during October-July. In August-September when the material was nearly a year old, its viability gradually diminished to *nil*. Even storage at 40°-50°F. inside a frigidaire did not prolong the life of teleutospores beyond a year or so.

Freshly formed teleutospores required a longer period of soaking in water than the mature ones for germination to commence. Minimum time taken by the latter was found to be six hours.

(i) Cardinal temperatures for the germination of teleutospores

From information available in literature it appears that teleutospores of *Puccinia graminis* do not germinate and produce sporidia above 25°C. Melhus, Durrell and Kirby [1920] stated that sporidia formation may occur only between 5° and 25°C. but seems most profuse at 20°C., while Lambert [1929] observed that the teleutospores germinated well at 12°—18°C. but most consistently at the latter temperature. Verwoerd [1931] found that temperatures above 22°C. were unsuited for the germination of teleutospores of black rust and infection of barberries in South Africa. According to Cotter [1932] teliospores of *P. graminis* rarely if ever germinate and produce and liberate sporidia at temperatures higher than 26° C. and a range of 12° to 21°C. gave the most favourable results. As recorded by Mehta [1940] all tests made in this country with teleutospores of *P. graminis tritici* between 50° and 65°F. gave the best germination.

In order to determine the range of temperature that is congenial for the germination of teleutospores of the rust under study, as well as to see in which season temperature conditions prevailing in Simla are suited for their germination, tests were made twice a month in the Stephenson's screen and a record of temperature was kept. Results are given in Table II.

TABLE II

Germination of teleutospores of black rust of *Agropyron* under different conditions of temperature prevailing at Simla. All tests were made in the Stephenson's screen.

Period of floating teleutospores on water.	Percentage germination	Average temperature in degrees F.		Remarks
		Minimum	Maximum	
Material was collected from Taradevi on 15-9-40 and stored in a room at Simla :				
8—10 October, 1940	60	57	68	
15—17 October, 1940	60	55	68	
1—3 November, 1940	75	53	66	
15—17 November, 1940	70	44·5	62·5	
1—3 December, 1940	100	43	59	
15—17 December, 1940	90	40	53·5	
6—8 January, 1941	0*	31	40	* Simultaneous tests in the heated greenhouse (48°—65° F.) gave 80—90 per cent germination
16—20 January, 1941	0*	29†	40	
1—2 February, 1941	90	39	53	
8—10 February, 1941	0*	28	40	† Minimum temperature was 26° F. on 19 January
14—16 February, 1941	100	39	48	
1—3 March, 1941	100	42	62	
15—16 March, 1941	90	50	71	
1—3 April, 1941	100	48	68	
15—16 April, 1941	100	56	74	
1—4 May, 1941	50	68	88	
15—17 May, 1941	70	56	70	
2—4 June, 1941	60	53	68	
15—17 June, 1941	50	60	72	
1—4 July, 1941	40	60	69	
15—17 July, 1941	10	58	70	
Material collected from Sanahan on 15-12-40 and stored in room at Simla :				
18—20 July, 1941	70	58	70	
1—4 August, 1941	30	60	68	
15—17 August, 1941	10	64	68	
1—4 September, 1941	T*	56	70	* Low viability was probably due to age of material, otherwise the temperature appears to be suitable for germination
15—18 September, 1941	0*	60	79	
Material collected from Taradevi on 29 September, 1941 :				
1—4 October, 1941	40‡	56	70	‡ Percentage germination soon after collection
15—17 October, 1941	50	52	72	
1—4 November, 1941	50	48	68	
15—17 November, 1941	60	44	63	
1—4 December, 1941	50	50	70	
15—17 December, 1941	75	42	63	
1—4 January, 1942	80	34	52	
14—20 January, 1942	0+*	28	40	+* Simultaneous tests at 50°-54° F. gave 60 per cent germination on 16 January
19—21 January, 1942	10**	30	50	** 50 per cent germination was noticed at 42°—50° F.
9—11 February, 1942	100	40	52	
20—22 February, 1942	0+*	30	38	+*50 per cent. germination was noticed at 42°—50° F.
2—4 March, 1942	90	40	60	
15—17 March, 1942	80	48	70	
1—4 April, 1942	75	53	74	
15—17 April, 1942	90	43	59	
1—3 May, 1942	90	62	81	
14—16 May, 1942	80	53	72	
4—6 June, 1942	70	66	86	

From the data supplied in Table II it is clear that teleutospores of black rust of *Agropyron* germinate very well between 40° and 88° F. Germination tests carried out under controlled conditions in an incubator also show that satisfactory germination takes place between 40° and 90° F. and practically none below and above that range. It is interesting to note that it was found impossible to germinate teleutospores of wheat, oats and rye stem rusts outside 45°—70° F.

It is also apparent from Table II that temperature is generally suitable for the germination of teleutospores of the rust under study throughout the year at Simla, except during winter when the temperature at times drops below 40°F. It may, however, be pointed out that, besides temperature, saturated atmospheric humidity and presence of young leaves are important factors in the successful infection of barberries. Since these conditions are present in abundance during the rainy season (June-September) in the Simla hills, infected barberries are so common at that time.

(ii) *Influence of exposure to high temperatures on the viability of teleutospores*

The viability of teleutospores may be greatly affected by exposure to high temperatures subsequently to their formation. Stakman, Kirby and Thiel [1921] found that teliospores of stem rust formed in the northern States of the United States, when kept in the south, produced no infection on barberries, which are commonly infected in the north. Lambert [1929] also observed that teleutospores formed during May and June in States like Texas, Oklahoma, Southern Kansas, etc., are killed by exposure to hot summer in the months of July-September. According to Stakman [1934] the absence of infection on barberries in the far south of U. S. A. is due to the loss of viability of teliospores during the hot summers. Novotelnova [1935] observed that teleutospores of *Puccinia graminis avenae* are killed after exposure to 30° C. for 24 hours. Mehta [1940] remarked that it is very unlikely for the teleutospores to retain their viability after exposure to summer heat in the plains of India, even if germinable at the time of formation.

It has been found that teleutospores of *Agropyron* rust formed in September-October and exposed to natural conditions of weather at Simla are viable in June-July of the following year (see Table I). This shows that the temperature conditions prevailing in winter, spring and summer at Simla do not affect adversely their germinability.

Influence of exposure to higher temperatures on the viability of teleutospores of *Agropyron* rust was experimentally determined by keeping viable material in a water bath at different temperatures between 90° and 120° F. for 6 to 24 hours. Germination of the heated material and that of control was tested at 50°—65° F. It was found that exposure for 24 hours at 90°—100° F. reduced the germination from 90 to 60 per cent. Only 40 per cent germination was observed after 24 hours' exposure at 100°—110° F. and 20 per cent at 110°—120°. No viability was left after the material was exposed at 110°—120° for 48 hours. It is interesting to note that teleutospores of wheat stem rust lost all viability after exposure to 100—110° for 24 hours and 110°—120° for 18 hours.

One hundred teleutospores were studied and found to measure $38{\cdot}59$—$56{\cdot}75 \times 13{\cdot}62$—$20{\cdot}43\,\mu$ and the size of the largest number of spores was found to be $45{\cdot}4 \times 18{\cdot}16\,\mu$.

Germinating teleutospores taken from *Agropyron semicostatum* are photographed in Plate I, fig. 1.

Inoculations on species of *BERBERIS*

A large number of inoculations was made with sporidia of this rust on different species of *Berberis* growing commonly in the neighbourhood of Simla, viz. *B. lycium* Royle, *B. aristata* DC and *B. coriaria* Royle. In addition, inoculations were made on *B. petiolaris* Wall. found in a restricted area at Narkunda (alt. 9,200 ft., 40 miles east of Simla), *B. pseudumbellata* Parker obtained from Tangmarg (alt. 7,200 ft. in Kashmir), *B. umbellata* Wall. found at Singlila in Darjeeling and *B. tinctoria* Lesch. obtained from the Nilgiris. *B. vulgaris* Linn., known to be most susceptible to all the 'Specialized forms' of *Puccinia graminis* Pers. was also inoculated several times, simultaneously with other species. It may be stated here that true *Berberis vulgaris* Linn. does not occur in India [Schneider, 1905]. For that reason, plants raised from seed obtained from England and the U. S. A. were used.

FIG. 1. Germinating teleutospores of *P. graminis agropyri* ×300.

FIG. 2. Arrangement for inoculating young shoots and leaves of barberry bushes with sporidia.

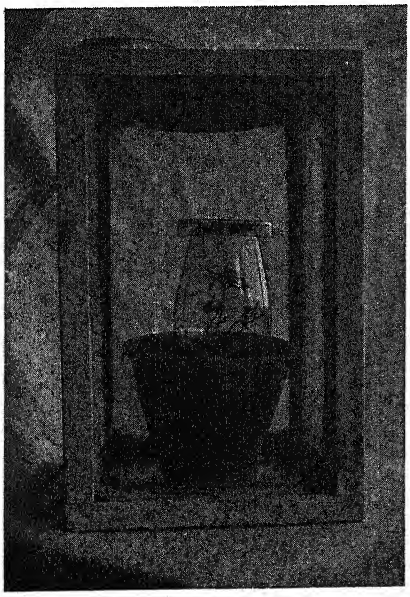

FIG. 3. Arrangement for inoculating plants of *Berberis* grown in pots.

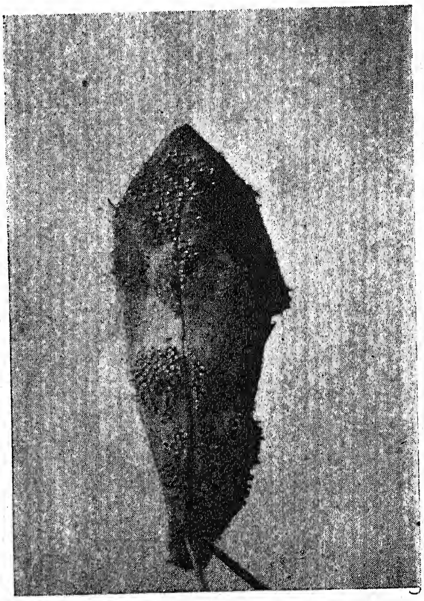

FIG. 4. Leaf of *Berberis lycium* Royle, 10 days old when inoculated on the bush under natural conditions. (×1½).

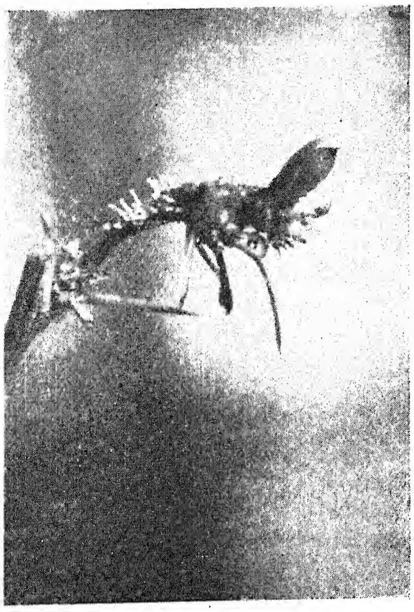

FIG. 1. Young shoot of *B. Lycium* Royle, 3-5 days old at the time of inoculation in the greenhouse (natural size).

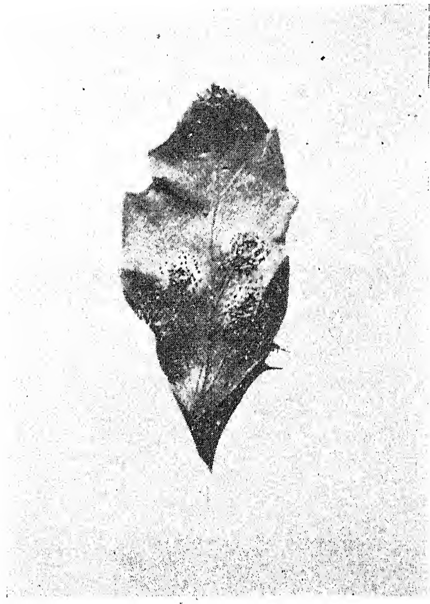

FIG. 2. Leaf of *B. aristata* DC. seven days old when inoculated on the bush under natural conditions (natural size).

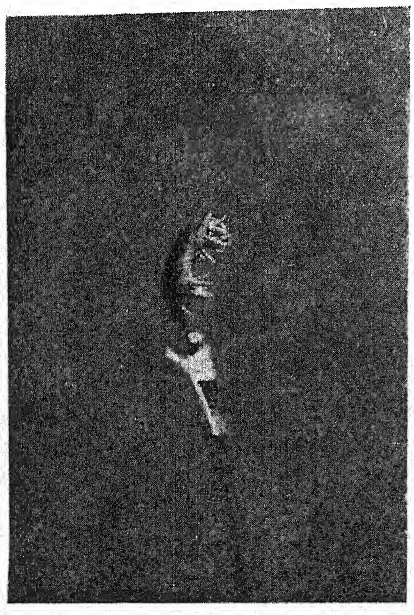

FIG. 3. Leaf of *B. coriaria* Royle five days old at the time of inoculation in the greenhouse (natural size).

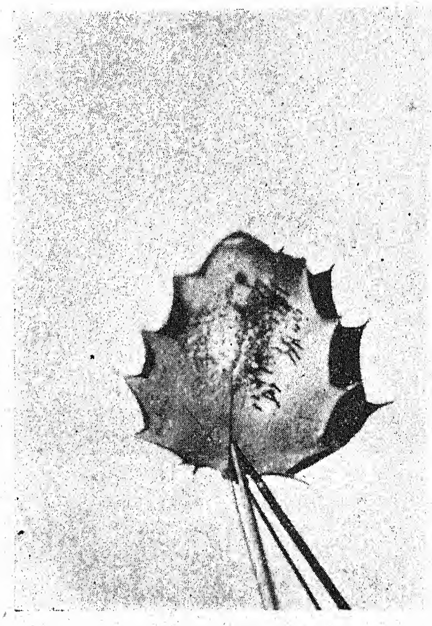

FIG. 4. Leaf of *B. umbellata* Wall, four days old at the time of inoculation in the greenhouse (× 2).

Inoculations were made on all the species in the open, under natural conditions, as well as in the greenhouse. For *B. lycium* and *B. aristata* young leaves and shoots on bushes growing in the laboratory compound were inoculated. The shoot was covered with butter paper bag before the leaves appeared, in order to safeguard against wind-borne infection. Each leaf was marked on the day it started unfolding with dated paper label for the determination of its age at the time of inoculation. The paper bag was removed before inoculation and the young shoot and leaves well sprayed with tap water in the morning and covered with a broad glass tube closed at one end. The glass tube was lined with wet blotting paper and the other end plugged with wet cotton wool after inserting the young shoot to make it turgid for inoculation. The young shoot was uncovered in the evening and inoculated with a platinum loop dipped in a suspension of germinating teleutospores in fresh tap water. Pieces of straw bearing teleutosori were stuck in the wet blotting paper lining and the glass tube and cotton wool plug replaced. The whole apparatus was supported with cotton thread on other shoots of the bush as shown in Plate V, fig. 2. On the fourth day (during this period the inoculated shoot was shaded from direct sun with a piece of cloth), the glass tube was removed and replaced with a butter paper bag and a label was put on it indicating the date of inoculation. This is also shown in the photograph. The bag was removed after the appearance of pycnia to let the insects visit the infected parts.

Fresh leaves of other species were inoculated in the open on plants grown in pots. The technique of inoculation was the same as described by Mehta [1940], and illustrated in Plate V, fig. 3. The glass case and the chimney were removed on the fourth day from the date of inoculation and the inoculated parts covered with butter paper bag which was taken off when the pycnia appeared. The plants were screened from direct sun during the period they remained under the glass case.

The same method of inoculation was employed in the greenhouse tests except that it was not necessary to put on the butter paper bag after the plants were uncovered.

Successful infection, resulting in the formation of aecidia on susceptible species, was obtained under natural conditions throughout the year at Simla (temperature 40°—85° F.). Generally, pycnia appeared in 7—10 days after inoculation and aecidia within 15—20 days. At lower temperatures, as expected, the incubation period was longer and aecidia were formed in 20—30 days. Aecidia formed under natural conditions were short and accompanied by marked swelling of the leaf, while those produced in the greenhouse were long and without any swelling of the affected parts. Mains [1924] stated 'Oftentimes in the greenhouse the peridia of aecidia do not open but project out as long cylindrical column from which no spores are shed'.

The results of inoculations made on different species of *Berberis* are summarized below :

(i) *Berberis lycium* Royle is found very commonly in the neighbourhood of Simla. Seedlings as well as older plants have proved to be heavily susceptible. Fresh leaves of seedlings and plants raised from root-wood have produced aecidia up to the age of 16—18 days in the greenhouse but only 12—14 days when inoculated on bushes under natural conditions. Infection occurs on leaves, stems, spines and petioles, although heaviest infection was noticed on the leaves, probably because of larger surface being exposed to rust attack. Infected leaves are photographed in Plate V, fig. 4 and Plate VI, fig. 1.

Reaction of this species to other 'Specialized forms' of *Puccinia graminis* as well as its distribution in this country have been supplied by Mehta [1940] and need not be repeated here.

(ii) *B. aristata* DC., also found commonly in Simla and the higher altitudes of the Simla hills, showed moderate infection. Leaves up to the age of 8—10 days in the case of young plants raised from seed and 6—8 days in plants raised from root-wood produced aecidia in the greenhouse, while under natural conditions only leaves up to the age of 6—8 days got infected on the bushes. A photograph of an infected leaf is reproduced in Plate VI, fig. 2.

For the reaction of this species to other 'Specialized forms' of *Puccinia graminis* as well as its distribution in this country, reference may be made to Mehta [1940].

(iii) *B. coriaria* Royle does not occur near Simla proper and in the lower altitudes of the Simla hills. It is common between Mattiana (7,500 ft.) and Narkunda (9,200 ft.). Fresh leaves up to the age of 10--12 days got infected in the greenhouse on seedlings and young plants raised from seed. In plants raised from root-wood, on the other hand, aecidia were produced on leaves 8—10 days old in the greenhouse and 6—8 days old when plants were inoculated under natural conditions in the open. Infection was moderate to heavy in every case. Infected leaves are photographed in Plate VI, fig. 3.

Mehta [1940] has described the reaction of this species to other ' Specialized forms ' of *P. graminis* and supplied its distribution in India.

(iv) *B. petiolaris* Wall. [Syn. *B. pachyacantha* Koehne, as described by Parker [1924], and *B. vulgaris*, var. 1 *vulgaris* proper according to Hooker (1875)], is not found near Simla. It grows in a restricted area at Narkunda (alt. 9,200 ft.).

Some inoculations were made only on fresh leaves produced on plants raised from root-wood because seed of this species was not available. No infection took place even on very young leaves, 2-4 days old, in the greenhouse, although fresh leaves of *B. lycium* inoculated simultaneously got heavily infected.

There is no information in literature on its reaction to *P. graminis* in other countries. Mehta [1940] observed that it is not infected by sporidia of *P. graminis tritici* in India.

Butler and Bisby [1931] reported the occurrence of aecidia of *P. graminis* Pers. on *B. vulgaris* in the Himalayas, but as already stated, true *B. vulgaris* Linn. is not found in India.

(v) *B. pseudumbellata* Parker [Parker, 1924] does not occur in the Simla hills. It is found in Kashmir near Tangmarg where Stewart collected aecidia on it which were identified by Arthur and Cummins [1933] as belonging to *P. graminis* Pers.

For want of a larger number of plants only a few inoculations could be made resulting in the formation of pycnia on two days old leaves on plants raised from root-wood. Fresh leaves of *B. lycium* inoculated simultaneously got heavily infected and produced aecidia. Work could not be done on seedlings of this species because good seed was not available.

There is no information in literature on its reaction to any ' Specialized form ' of *P. graminis* Pers.

(vi) *B. umbellata* Wall. also is not found in the Simla hills and work was done on plants raised from seed and root-wood obtained from Singlila in Darjeeling. Light infection was produced in the greenhouse on 4—6 days old leaves of seedling and young plants grown from seed resulting in the formation of aecidia on some of them. A photograph of a four day old leaf infected in the greenhouse is reproduced on Plate VI, fig. 4. Only pycnia were formed on leaves up to the age of four days in plants raised from root-wood.

The reaction of this species, from information available in literature, to other ' Specialized forms ' of *P. graminis* and its distribution in India have been supplied by Mehta [1940].

(vii) *B. tinctoria* Lesch. was obtained from the Nilgiris because it does not occur in the Simla hills. Aecidia were produced in the greenhouse and outside on leaves up to the age of six days on seedlings and young plants grown from seed and on leaves 4-5 days old on plants raised from root-wood. The infection was light to moderate.

A photograph of a four day old leaf infected under natural conditions is reproduced in Plate VII, fig. 1.

There is no information in literature regarding its reaction to *P. graminis*.

According to Hooker [1875] and Fyson [1932], *B. tinctoria* Lesch. is a variety of *B. aristata* but Schneider [1905] has put it as a separate species. It is found only in the Nilgiris and the Palni hills in this country.

(viii) *B. vulgaris* Linn. was raised from seed obtained from England and the U. S. A. because, as already stated, true *B. vulgaris* Linn. does not occur in India. Results of inoculations made on fresh leaves of this species with sporidia of black rust of *Agropyron* are very interesting because, contrary to expectations, no infection was produced even on leaves two days old on the seedlings.

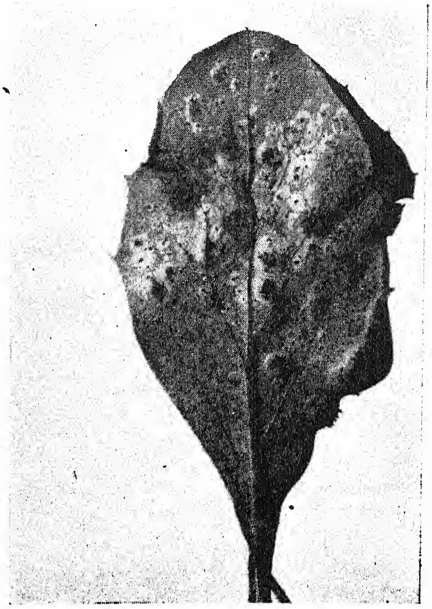

FIG. 1. Leaf of *B. tinctoria* Lesch., four days old at the time of inoculation on plants raised from root-wood and growing under natural conditions at Simla laboratory. ($\times 1\frac{1}{2}$).

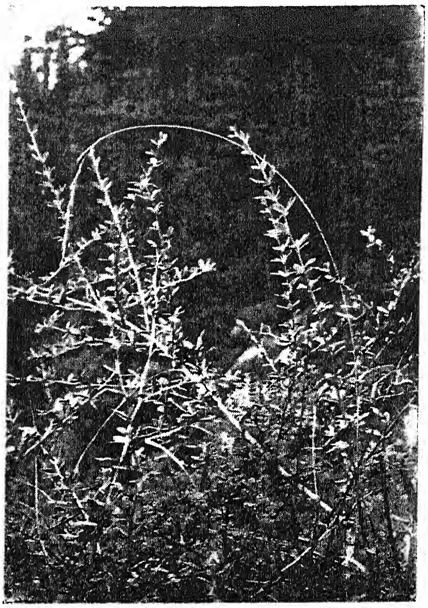

FIG. 2. Infected *B. lycium* and rusted *Agropyron samicostatum* growing together at Sanahan.

FIG. 3. Infected leaves of *B. lycium* found near Simla. (natural size).

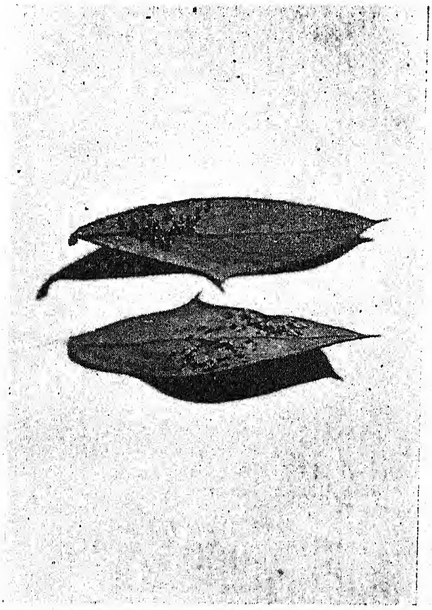

FIG. 4. Infected leaves of *B. lycium* found near Simla. (natural size).

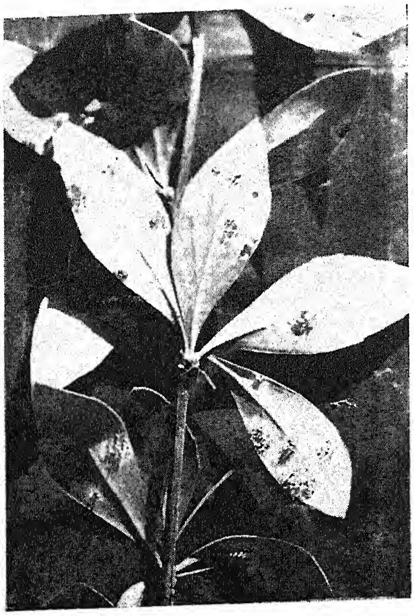

FIG. 1. Infected leaves of *B. aristata* found near Simla. (natural size).

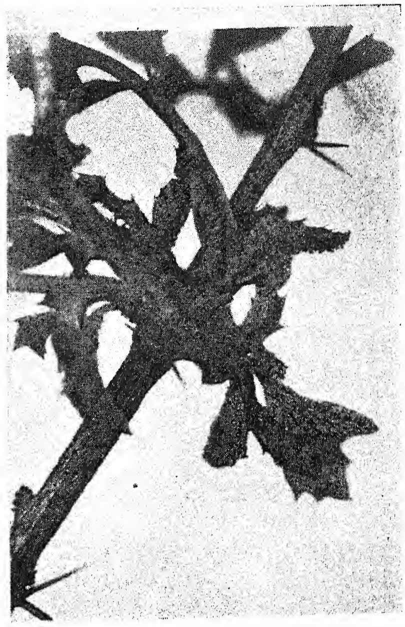

FIG. 2. Deformed shoot with leaves heavily infected with *Aecidium montanum* (slightly reduced).

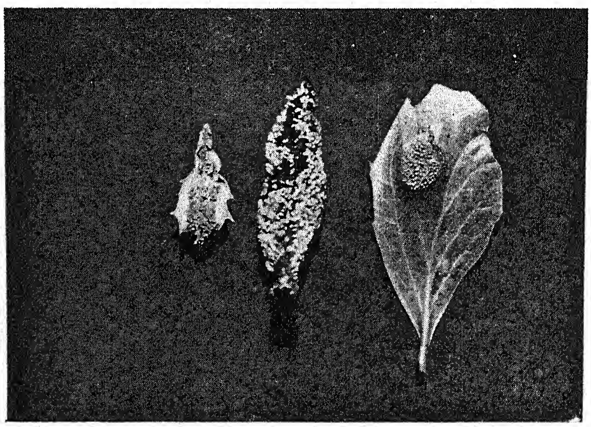

FIG. 3. Infected leaves of *B. coriaria* found on bushes at Narkunda. Two leaves on the left bear *Aecidium montanum* (natural size).

In a large number of tests made on seedlings as well as on plants up to six years old not a single leaf got infected, and even pycnia were not formed on any of them. All the leaves remained perfectly healthy. Fresh leaves of *B. lycium* inoculated simultaneously in every test got heavily infected.

It is well-known that *B. vulgaris* Linn. is heavily infected by all the 'Specialized forms' of *P. graminis*. Arthur [1929] has stated that *B. vulgaris* is a favourable host for all except one of the races recognised in the sporophytic stage. For the one exception, viz., *P. graminis phlei-pratensis*, a congenial aecial host is unknown, for this race differs from others in not infecting *Berberis vulgaris* to any extent. Verwoerd [1931] successfully infected this species with teleutospores of *P. graminis tritici*, *P. graminis avenae* and *P. graminis secalis* in S. Africa. Cotter [1932] obtained infection of leaves 12-15 days old several times in the U. S. A. He stated that '*Berberis vulgaris* is generally supposed to be the species of barberry most susceptible to the attack of *Puccinia graminis*'. Levine and Cotter [1932] have quoted this species to be heavily susceptible to *P. graminis tritici*. According to Mehta [1940], leaves up to the age of 12 days are heavily susceptible to sporidia of *P. graminis tritici* in this country.

The significance of the failure of infection of *Berberis vulgaris* Linn. alone by the sporidia of the rust under study on its classification is fully discussed later in this article.

One hundred aecidiospores were measured from *B. lycium* infected in the greenhouse and found to range from 20·43—27·24×17·02—22·7μ (average 23×19μ). Aecidia are hypophyllous and measure about 10—14 mm. in length when produced in the greenhouse and 2-3 mm. if formed under natural conditions in the open.

Aecidiospores of *P. graminis tritici* produced on *B. lycium* in the greenhouse under indentical conditions measured 18·16—22·7×15·89—20·43μ (average 20×17μ) and aecidia were 12-14 mm. in length.

INOCULATIONS WITH AECIDIOSPORES ARTIFICIALLY PRODUCED

Inoculations made on *Agropyron semicostatum*, *A. longearistatum*, and *A. repens*, var. *aristatum* (Kashmir) with aecidiospores produced artificially on species of *Berberis* described above resulted in the formation of uredo-sori in every case.

Simultaneous inoculations made on wheat (*Triticum* spp.), barley (*Hordeum vulgare*), rye (*Secale cereale*) and oats (*Avena sativa*) with aecidiospores so produced in the laboratory and with uredospores obtained therefrom on *Agropyron* gave negative results. The varieties of wheat, barley, rye and oats on which inoculations were made are :

(i) Wheat :

1. *Triticum compactum* var. Little club
2. *T. vulgare* vars. Marquis and Agra local
3. *T. durum* var. Spelmar
4. *T. monococcum* var. Einkorn
5. *T. dicoccum* var. Khapli

(ii) Barley:

1. *Hordeum vulgare* var. Agra local

(iii) Rye :

1. Petkusar
2. Colourless
3. Dakold
4. Rosen
5. A susceptible variety obtained from Agricultural College, Lyallpur

(iv) Oats :

1. White Tartar
2. Joanette
3. Richland
4. Agra local

Observations on infected Barberries and rusted *Agropyron* in the Simla Hills

Search for the rusted grass near infected barberries was continued at other places in the Simla hills after September, 1940, when both the hosts were first noticed growing together at Taradevi. Infection on bushes of *B. lycium* and *B. aristata* is quite common during June—August near about Simla and in most cases rusted *Agropyron* was met with in their neighbourhood in August—September. At some places infected barberries were found growing along with plants of *Agropyron*. Plate VII, fig. 2 shows the photograph of one such bush found at Sanahan (a village near Simla) on 26 August, 1941. There were old aecidial cups on *B. lycium* and the grass had uredo and teleuto pustules on the stems.

Aecidia have been noticed during May—July on *B. aristata* in the higher altitudes at places like Kufri (8,200 ft.), Theog (7,500 ft.) and Mattiana (7,900 ft.) but the leaves are never so heavily infected as those of *B. lycium*. In most cases straw of *Agropyron* with teleuto-sori was found near diseasde bushes. Inoculations made on Agra local wheat, barley, oats, rye and *Agropyron semicostatum* with aecidiospores from *B. lycium* and *B. aristata* found near Simla as well as at higher altitudes resulted in the infection of *Agropyron* only.

At Theog and Mattiana, plants of *Agropyron* with uredo and teleuto pustules were found near infected barberries in the first week of October, 1941, when those places were visited. Leaves of *B. lycium* and *B. aristata* found infected on the bushes are photographed on Plate VII, figs. 3 and 4 and Plate VIII, fig. 1.

Two kinds of aecidia were observed on *B. coriaria* at Narkunda (altitude 9,200 ft.) during May—June; one type resembling *Aecidium berberidis* (?) and the other answering to the description of *Aecidium montanum* Butl. It appears that leaves bearing the former either get infected in September—October but produce aecidia not before the following spring on account of very low temperature during winter at that altitude, or, the teleutospores over winter and germinate and produce infection early in spring. Nothing can be said for *A. montanum*. Leaves of *B. coriaria* bearing the two kinds of aecidia are photographed on Plate VII, fig. 3 and a deformed shoot with leaves heavily infected with *Aecidium montanum* is shown in Plate VII, fig. 2. Inoculations made on the spot with aecidiospores from both kinds of aecidia separately, gave negative results on wheat, oats, rye and *Agropyron semicostatum* in the case of *Aecidum montanum* but resulted in the production of uredo pustules only on *Agropyron* with the other kind of aecidia, resembling *A. berberidis*. These inoculation were repeated several times in the laboratory at Simla but with the same results. *Agropyron* alone was infected with spores from un-deformed leaves only. This explains the failure of infection all these years on wheat and barley seedlings with aecidiospores occurring in nature as reported by Mehta [1933, 1940].

Aecidiospores from both kinds of aecidia remained viable for nearly a month at room temperature (60°—70° F.) at Simla.

Measurements of aecidia and aecidiospores taken from *Berberis coriaria* bushes are supplied in Table III.

Table III

Dimensions of Aecidia and Aecidiospores of *Aecidium montanum* and *A. berberidis* (?) found in nature on *Berberis coriaria* and of *A. berberidis* (?) found on *B. lycium*

Type of Aecidum	Length of Aecidia	Aecidiospores	
		Size limits in μ	Average in μ
B. coriaria			
1. *A. montanum*	2—3 mm.	24·97—34·05×18·16—27·24	29·51×24·97
2. *A. berberidis* (?)	1—2 mm.	19·29—29·51×17·02—22·7	24·43×19·87
B. lycium			
1. *A. berberidis* (?)	1—2 mm.	19·29—27·24×15·89—22·7	24·97×19·29

The Uredo-stage

Wherever found, Agropyron was heavily infected ; stems, leaves and ears being involved. Infection with uredo-stage was never so heavy as with the teleuto-stage.

A culture of the rust under study has been maintained in the greenhouse ever since it was first collected at Taradevi. The incubation period was found to vary between 8 and 15 days according to weather.

In general, the shape of uredospores is similar to that of uredospores of black rust on wheat oats or rye. If, however, a large number of spores is measured from cultures grown on their congenial hosts, it is found that there are significant differences in the size of uredospores of the four rusts. For the sake of comparison, the dimensions of uredospores of each of these rusts is given in Table IV. The results were obtained from the study of one hundred spores of each rust as represented by a mixture of six physiologic races of *Puccinia graminis tritici*, four races of *P. graminis avenae*, as reported to occur in this country by Mehta [1940], a culture of *P. graminis secalis* originally started from material obtained from Cambridge, England and a culture of the rust under study on seedlings of *Agropyron semicostatum*. All the spores were taken from greenhouse cultures grown under identical conditions.

Table IV

Dimensions of uredospores of *Puccinia graminis tritici*, *P. graminis avenae*, *P. graminis secalis* and the *Agropyron* rust taken from cultures maintained in the greenhouse

Specialized form	Size limits in μ	Average in μ
P. graminis tritici	22—33 × 13·2—22	28 × 17·6
P. graminis avenae	17·6—37·4 × 11—19·8	26·4 × 17·6
P. graminis secalis	24·97—34·05 × 13·62—18·16	28·37 × 15·89
Agropyron rust	20·43—31·78 × 12·48—18·16	26·1 × 14·7

It is clear from the data supplied in Table IV that uredospores of *Agropyron* rust are smallest out of all the four rusts studied.

Like others, the uredospores of *Agropyron* rust have four equatorial germ-pores and there are no mesospores or paraphyses.

In general appearance the pustules of the four rusts are similar. The shape is usually oval to broadly linear but when the infection is heavy the sori coalesce with one another and form long pustules. In greenhouse cultures on leaves of seedlings the pustules of *Agropyron* rust are linear and measure 2—3 mm. when ripe.

Uredospores from pure cultures of the *Agropyron* rust were put on seedlings of Agra local wheat barley, oats and Lyallpur rye but no infection was produced on any of them. Differential hosts of *P. graminis tritici* [Stakman & Levine, 1922], *P. graminis avenae* [Stakman, Levine and Bailey, 1923] and *P. graminis secalis* [Levine and Stakman, 1923] were next inoculated but the results were negative.

A dozen representative wild grasses were also inoculated with uredospores and the results are supplied in Table V.

TABLE V

Results of inoculations with uredospores of black rust of Agropyron semicostatum *on seedlings of some wild grasses*

Serial No.	Name of grass	No. of tests	No. of leaves inoculated	No. of leaves infected	Degree of Infection
1	*Bromus patulus*	2	20	20	Heavy
2	*Brachypodium sylvaticum*	2	20	0	No infection
3	*Avena fatua*	2	18	0	Do.
4	*Dactylis glomarata*	2	24	0	Do.
5	*Agrostis alba*	2	20	0	Do.
6	*Poa pratensis*	2	25	0	Do.
7	*Phalaris minor*	2	22	0	Do.
8	*Festuca ovina*	2	20	0	Do.
9	*Panicum Crus-galli*	2	24	0	Do.
10	*Aira flexuosa*	2	22	0	Do.
11	*Agropyron repens*	2	20	20	Heavy
12	*A longearistatum*	2	20	20	Do.
13	*A. semicostatum*	2	20	20	Do.

Seed of Nos. 1, 2, 3, 7, 12 and 13 were collected by the writer near Simla; Nos. 4, 5, 6, 8 and 10 were obtained from Welsh Plant Breeding Station, Aberystwyth; No. 9 was supplied by the Forest Botanist, Dehra Dun and No. 11 was collected from Kashmir.

It will be seen from the above table that, with the exception of *Bromus patulus* and three species of *Agropyron*, no other grass was infected. This is very significant because these grasses are known to be congenial hosts for one or the other ' Specialized forms ' of *Puccinia graminis* recognised so far [Grove, 1913; Stakman and Piemeisel, 1916, 1 and 2; Arthur, 1929]. *Bromus patulus* has also been found to be a collateral host of *P. graminis tritici* in this country [Mehta, 1940].

Moderate infection was produced when *Agropyron longearistatum* and *A. semicostatum* were inoculated with uredospores of *P. graminis tritici* and *P. graminis secalis* but only weak infection was obtained with *P. graminis avenae*. On the other hand, none of the three hosts, wheat, rye or oats, got infected with the rust of *Agropyron* as stated before.

The effect of exposure to high temperatures on the viability of fresh uredospores was determined by putting infected leaves in an incubator between 90° and 120° F. The uredo-sori were nearly 7—9 days old in every exposure. The cut ends of the stalks were dipped in water in specimen tubes whereby the leaves remained quite fresh throughout the period of experiments. Germination was tested in tap water in hanging drops at room temperature (50°—60°F.).

Results show that between 90° and 100° there is no appreciable loss in the viability of the spores in 24 hours. At 100°—110° and 110°—120°, more than half the number of spores were killed in 18 and 6 hours, respectively, while no germination was noticed in the material exposed for 24 and 12 hours at those temperatures.

6 GENERAL DISCUSSION

From the evidence obtained during the course of these studies, it is clear that the rust found on *Agropyron semicostatum* and *A. longearistatum* in the Simla hills is *Puccinia graminis* Pers., the black stem-rust. Leaves, stems and ears are infected but the attack is heavier on the last two. The uredospores are ovate-oblong, yellowish brown, with four equatorial germ-pores. In size they are smaller than those of *P. graminis tritici*, *P. graminis avenae* and *P. graminis secalis*. There are no mesospores or paraphyses. Teleutospores are bi-celled, very much resembling those of stem rusts of other cereals in appearance and size. Morphologically, therefore, there is little to distinguish the rust under study from the stem rusts of wheat, oats or rye, except in the size of uredospores.

Physiologically, however, the differences are very apparent both in the gametophytic and sporophytic stages of the life cycle of the fungus. These are discussed below in detail.

(i) *Germination of teleutospores*

Teleutospores of the *Agropyron* rust have been found to germinate very well, without undergoing a period of rest, between 40° and 90°F. As recorded by different workers in India and abroad, and also found by the writer, teleutospores of wheat, oats and rye stem-rusts do not germinate outside 45°—70°F. and require a resting period.

It is interesting to note that, whereas teleutospores of wheat stem-rust lose all viability when exposed to high temperatures, those of the rust under reference gave 40 and 20 per cent germination after exposure for 24 hours to 100°—110° and 110°—120° F., respectively.

(ii) *Infection of species of Berberis*

'Specialized forms' of *Puccinia graminis* have been recognised on the basis of their host specialization on the sporophytic side; very little information is available concerning the behaviour of their gametophytes. As stated by Arthur [1929] *Berberis vulgaris* is a favourable host for all except one form hitherto recognised in the sporophytic stage. For the one exception, *viz.*, *P. graminis phlei-pratensis*, a congenial aecidial host is unknown, because, unlike others, *Berberis vulgaris* is not infected at all. Largely for that reason, the rust of *Phleum pratense* has been raised to the rank of a distinct species, *Puccinia phlie-pratensis*.

The *Agropyron* rust differs from other forms of *Puccinia graminis* in its inability to infect *Berberis vulgaris* at all. It has been shown that even young leaves at the age of two days in the case of seedlings did not get infected; there was no evidence of any puncture or injury of the leaf. Unlike *Puccinia phlei-pratensis*, however, several other species of *Berberis* are heavily infected by this rust, resulting in the formation of aecidia. On all these species infection is very much heavier than with the wheat stem-rust and slightly older leaves proved to be susceptible. For this reason, there is no justification in assigning a distinct specific name to this rust. It is quite likely that other forms may behave differently towards various species of *Berberis*, or individual forms as at present recognised by their host range on the sporophytic side, may be further divisible on the basis of their behaviour on different species of *Berberis*.

A parallel case is available in *Puccinia coronata* Corda. Klebahn [1895, 1896] separated it into two species, *P. coronifera* and *P. coronata* chiefly because the former produces aecidia on one group of species of *Rhamnus* while the latter develops aecidia upon another group. Within these two species several forms were recognised on the basis of their specialisation on grass hosts. Other investigators [Arthur and Fromme, 1920; Melhus, Dietz and Willey, 1922], however, prefer to retain all these races as under one species, *P. coronata* Corda, because one species or the other of *Rhamnus* is successfully infected by all of them.

(iii) *The uredo-stage*

Uredospores from pure cultures of this rust have failed to infect Agra local wheat, barley, oats and rye, all of which are heavily susceptible to their respective forms of black rust. Inoculations made on differential hosts of *P. graminis tritici*, *P. graminis avenae* and *P. graminis secalis* gave negative results. Seedlings of *Avena fatua*, *Dactylis glomerata*, *Agrostis alba*, *Poa pratensis*, *Phalaris minor*, *Festuca ovina*, *Panicum Crus-galli* and *Aira flexuosa*, known to be congenial hosts for one or the other specialised form of black rust, also failed to get infected. Successful infection was produced only on *Bromus patulus*, *Agropyron repens*, *A. longearistatum* and *A. semicostatum*.

It is evident, therefore, that the rust under study cannot be placed under any of the known specialized forms of *Puccinia graminis* on the basis of its behaviour in the sporophytic stage also, and accordingly the name *Puccinia graminis agropyri* (Pers.) Mehta and Prasada is suggested for it.

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SUMMARY

The uredo-stage connected with aecidia so commonly found on species of *Berberis* in the Simla hills was discovered during these studies and a complete account of its life-history furnished.

The teleutospores germinate without a resting period between 40° and 90° F. Viability was greatly impaired after exposure to 100°—120° F. for 24 hours and no germination was obtained after 48 hours at 110°—120° F.

Moderate to heavy infection was produced on young leaves of *Berberis lycium*, *B. coriaria*, and *B. aristata*; light to moderate on *B. tinctoria* and light on *B. umbellata*. Only pycnia were produced on *B. pseudumbellata* while *B. vulgaris* Linn. and *B. petiolaris* did not get infected at all.

Inoculations made with aecidiospores produced artificially gave negative results on wheat, barley, oats and rye but uredostage was produced on three species of *Agropyron*, viz. *A. repens*, *A. semicostatum* and *A. longaristatum*.

Aecidiospores found in nature on *B. lycium* and *B. aristata* also infected only the three species of *Agropyron*. Two kinds of aecidia were noticed on *B. coriaria*. *Aecidium montanum* did not infect either the cereals or *Agropyron* but the other type, dealt with in this article, infected only the latter.

In nature leaves, stems and ears of *A. semicostatum* and *A. longearistatum* are found infected with uredo-and teleuto-stages. The uredospores lost their viability after 24 hours' exposure to 100°—110° F. No infection was produced on differential hosts of *Puccinia graminis tritici*, *P. graminis avenae* and *P. graminis secalis*. Seedlings of *Avena fatua*, *Dactylis glomerata*, *Agrostis alba*, *Poa pratensis*, *Phalaris minor*, *Festuca ovina*, *Panicum Crus-galli* and *Aira flexuosa*, known to be congenial hosts for one or the other specialized form of *Puccinia graminis*, also failed to get infected with uredospores of the rust under study. *Bromus patulus*, a collateral host of *Puccinia graminis tritici*, however, got infected.

Cross inoculations made with uredospores of *Puccinia graminis tritici* and *P. graminis secalis* resulted in moderate infection of the three species of *Agropyron*, while *P. graminis avenae* produced weak infection.

Results are discussed in detail to show that the rust is a new specialized form of *P. graminis* and the name *P. graminis agropyri* (Pers.) Mehta and Prasada is suggested.

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FIELD EXPERIMENTS ON RECLAMATION OF SALT LANDS IN BARAMATI OF BOMBAY DECCAN*

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(With plates IX—XI and six text-figures)

AMONGST the soil conditions affecting plant growth, the supply of plant nutrients and various other factors play a very important part.

It is well known that alkali soils are very sticky when wet and are impervious to water, and on drying form hard cakes at the surface. The intensity of these properties depends upon the quantity and conditions of colloids. It is, therefore, very essential to restore these soils to their normal conditions for plant growth in the initial stage of reclamation. This means that the soil has got to be brought to its original crumbly state or that the soil must be brought to good tilth. This can be achieved by deep tillage and addition of chemical fertilizers in combination with organic manures.

It is also observed that the soils, which are partially reclaimed, require careful tillage in the beginning as *vapsa* (optimum moisture) conditions remain for a temporarily short period than in the case of normal soils, specially during the wet season.

Another important point is the loss of organic matter usually occurring in alkali soils on leaching. Greaves [1927] in this connection has pointed out that 'Organic manures were essential for the restoration of alkali soils to a high state of productivity'. Thus after securing the necessary good tilth the next step to follow is the selection of crops resistent to alkaline or saline conditions.

Henderson [1920] in his note on practical salt land reclamation mentions about the rice crop as resistent to alkali salts. Similarly Mann and Tamhane [1910] suggest growing of salt rice from Konkan during the process of reclamation. They also recommend growing of *wal* (*dolicus lablab*) *chawali* (*Vigna catiang*) and Ambadi (*Babiscus cannabinus*). Puri [1935] has also worked out relationship between degree of alkalization and crop yield in the Punjab.

The work done at Baramati described in this paper is in connection with the study of lands affected with salt deposits with high subsoil water for years. Subsoil drainage reduced the high water table and made reclamation possible. The process of leaching out salts, the growing of successful crops, in the initial stages of reclamation according to the degree of salinization, and the stand of crops with progress of reclamation has been described. Basu and Tagare (1943) have described work at Padegaon in connection with (natural) alkali soil, called *chopan* with deep water table. It mainly deals with the nature of alkali soils and the various soils tests before and after crop growing.

In a reclamation process, therefore, every worker finds it quite essential to select crops which are resistent to salinity or alkalinity in the initial stage of reclamation.

Experimental technique

Laboratory and Field methods were the same as described in previous papers [Talati, 1941—1942].

Fig. 1 gives the area wherein all the experiments described in this paper were conducted. This area known as the Baramati Experimental salt area was one of the worst salt affected area under Deccan Canals. The subsoil water table was very high which ranged from ground level to 1—2 ft. from the surface while the solube salts varied from 2·5 to 4 per cent or even more. The whole area was underdrained by putting in pipe lines and open drains described in details by Inglis and Gokhale [1928] and attempts were then made at reclamation after reduction in the subsoil water table.

* This paper is in continuation of the paper published in *Indian Journal of Agricultural Science* (**XI, VI**) December 1941.

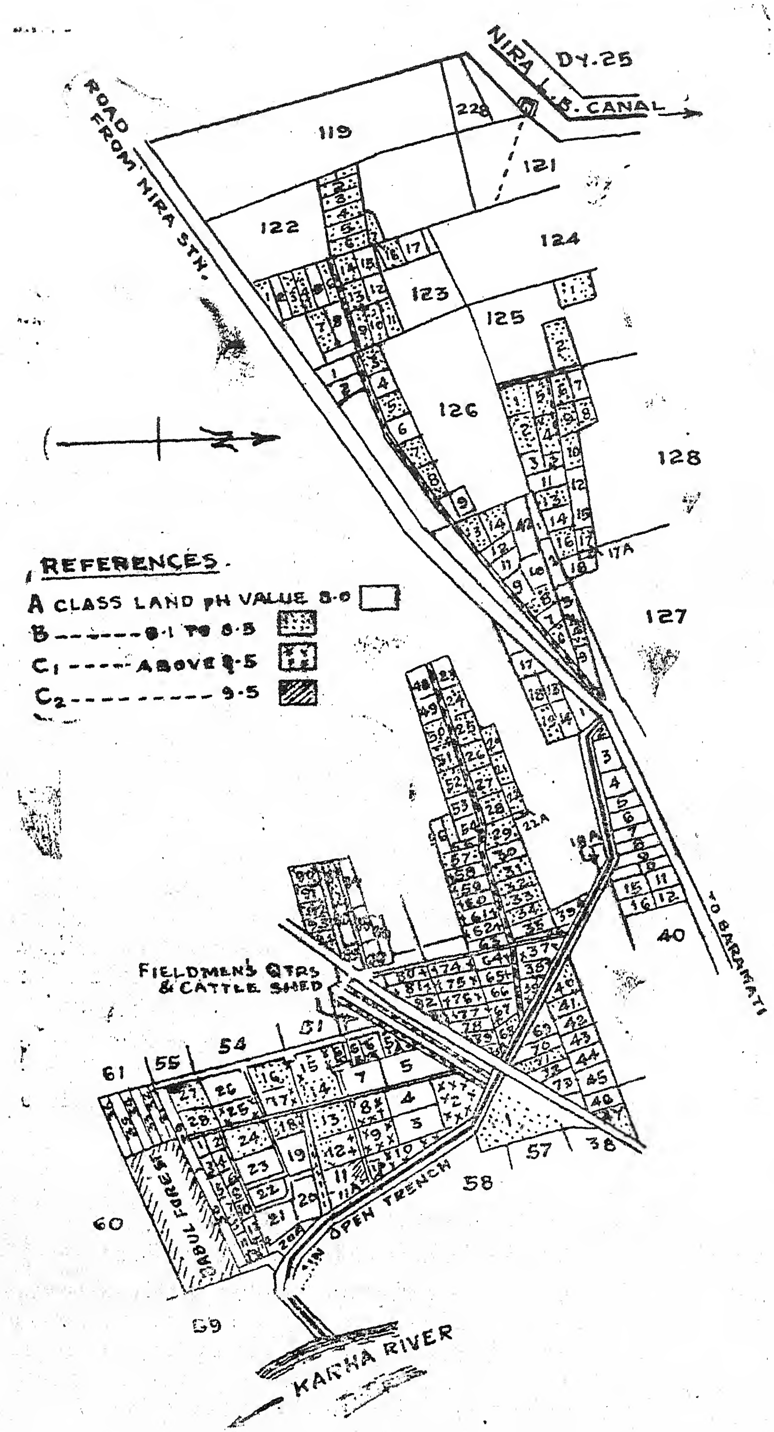

FIG. 1a. Experimental salt land Baramati. Nira Left Bank Canal
Scale 1 in. = 1,100 ft.

The description of the profiles affected with salts was as given in Table I.

TABLE I

Description of the profiles affected with salts.

Mixed saline soils		Saline soils
I	II	III
0—6 in. Fine black, loose and granular	0—12 in. Loose red soils	0—12 in. Grey black structureless
6—12 in. and 12—24 in. Black Soil compact fissured	12—24 in. Slightly stiff minute crystal, of gypsum	12—36 in. Clody grey black structure containing laminated lime
24—36 in. Greyish stiff	......	....
36—72 in. Yellowish clay large, prismoidal structure pieces, gypsum crystals	24—60 in. Prismoidal red clay with gypsum crystals or lime *kanker*	36—48 in. Fissured *chopan*
72—84 in. Massive *kanker*, fine sandy material easily breaking into powder (locally known as *mān*)	......	48—60 in. Yellowish prismoidal clay

The types of profiles described in Table I were leached to a stage in which crops could be established. For detailed description of the profiles for noting calcium-sodium concentration and other characteristics, the previous publication on this subject by Talati [1941] may be referred to.

Reclamation of mixed saline soils (consisting of mixed salts of calcium and sodium)

Leaching under field conditions.

A typically salt affected patch of about six acres was provided with adequate drainage. After the subsoil water was lowered to more than four feet from ground level, this area was ploughed up, levelled and divided into small plots of one *guntha* each according to the slope of the ground. Fig. 1b. will explain the layout more clearly.

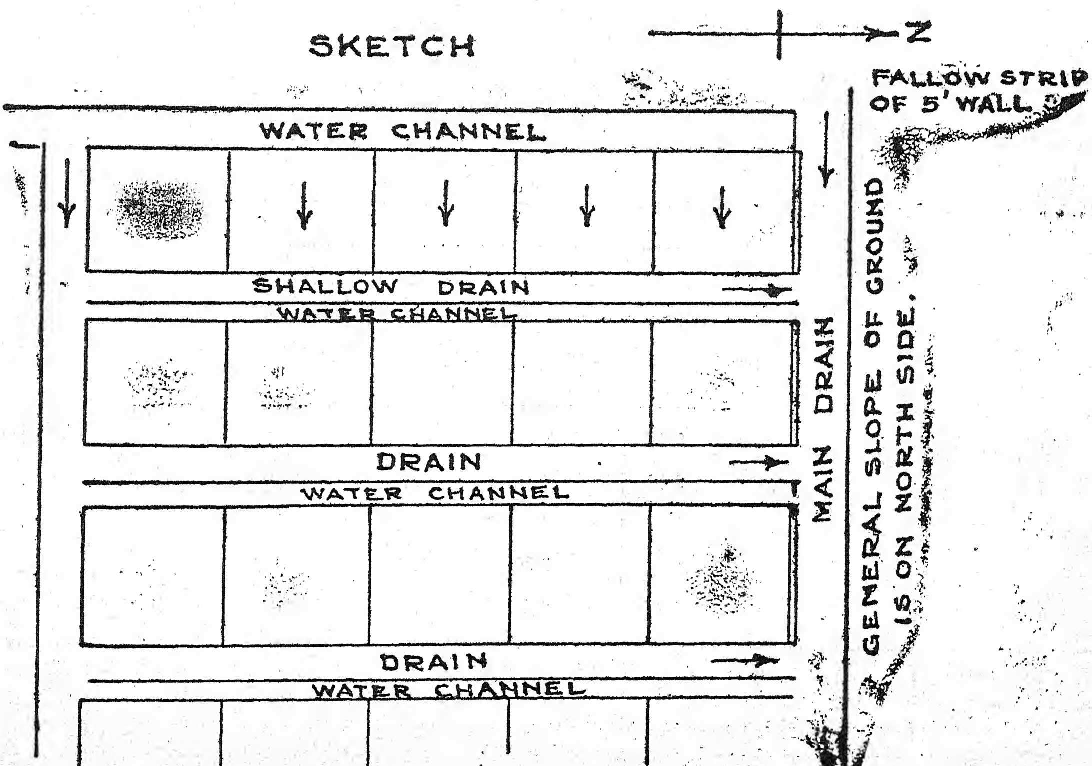

FIG. 1b. The slope of the ground

These plots were continuously under water for four months during monsoon from July to October and received about 160 acre inches of water. It was observed that about 25 in. of water evaporated (based on evaporimeter readings—Open Pan Evaporimeter, Indian type) leaving about 135 in. of water which drained through the entire soil profile, part going into subsoil drainage and part into the shallow gutters joining the main open drain.

Soil samples were collected at three typical spots before leaching; samples were also similarly collected after leaching. The results are set out in Table II.

TABLE II

Salt content of soil samples before and after leaching

Soil depth	Description of profile	Profile No. 1 Total salt percentage Leaching Before	Profile No. 1 Leaching After	Profile No. 2 Leaching Before	Profile No. 2 Leaching After	Profile No. 3 Leaching Before	Profile No. 3 Leaching After
0—6 in.	Salty black soil	2·65	1·00	3·00	1·025	3·50	0·925
6 in.—1 ft.	Ditto.	2·10	1·20	2·85	1·27	2·85	0·737
1—2 ft.	Yellow coloured loose soil	2·50	1·00	3·00	1·12	3·00	0·825
2—3 ft.	Ditto.	3·25	1·10	1·75	1·25	2·75	0·700
3—4 ft.	Fissured loose clay brownish	2·40	1·025	3·00	...	3·25	0·492

The results in Table II show good effects of leaching. The total soluble salts considerably leached out from about 3 per cent to less than 1 per cent. The reduction is, however, not uniform in all profiles which may be due to the nearness or otherwise of the main drain.

The *p*H values of the leached profiles were as shown in Table III.

TABLE III

The pH values of leached profiles

Soil depth	*p*H values Profile No. 1 Before leaching	Profile No. 1 After leaching	Profile No. 2 Before leaching	Profile No. 2 After leaching	Profile No. 3 Before leaching	Profile No. 3 After leaching
0—6 in.	8·46	8·06	7·84	7·72	8·02	7·44
6 in.—1 ft.	8·78	8·28	8·54	8·94	8·14	8·28
1—2 ft.	8·92	9·22	7·82	9·16	8·00	8·17
2—3 ft.	8·74	9·80	8·32	9·06	8·34	8·24
3—4 ft.	8·46	9·46	8·00	9·78	7·14	8·02

The results given in Table II show that *p*H values were appreciably reduced in the top six inches with an appreciable increase in lower horizons. This was because on leaching, sodium was hydrolised in lower horizons and this produced alkalinity.

The humus contents of these before and after leaching were estimated and the results given in Table IV were obtained.

TABLE IV

Humus contents before and after leaching

Soil depth	Humus percentage	
	Before leaching	After leaching
0—6 in.	0·3107	0·3346
6in. —1 ft.	0·3824	0·2868
1—2 ft.	0·4302	0·2868
2—3ft.	0·3585	0·2748
3—4 ft.	0·2987	0·2748

It will be seen that except for the top 6 in. there was considerable depletion of humus from 6 in. onwards.

Next year during monsoon, a crop of *dhaincha* (*Sesbania aculeata*), a robust green manuring crop, was tried. The stand of the crop was quite good. After the crop was removed, the soils were again examined for soluble salts, *p*H values and humus contents with results as indicated in Table V.

TABLE V

Soluble salt contents, pH values and humus percentage of soil

Soil depth	Percentage of total soluble salts	*p*H Values	Percentage of humus	Percentage of humus in normal soils of the same type nearby	Remarks
0—6 in.	0·30	8·04	0·32	0·82	Salts were found out from oven dry soils
6 in.—1 ft.	0·32	8·32	0·33	0·70	
1—2 ft.	0·27	9·08	0·37	0·52	
2—3 ft.	0·24	9·45	0·32	0·32	
3—4 ft.	0·62	9·24	0·28	...	

These results show that leached soils are deficient in humus as compared to normal soils of the type and hence it is essential to add bulky manures to enrich them and also to restore their tilth to normal conditions.

Saline soils of C type (alkali soils) had to be leached for three seasons to reduce excessive salts. The total inch-depth of irrigation applied for leaching in all the three seasons was about 275 acre inches which included evaporation amounting to 95 in. At the end soluble salts, *p*H values capillary rise and humus contents were noted ; the results are given in Table VI.

TABLE VI

Results of leaching of alkaline soils

Soil depth	Percentage of soluble salts	pH values	Percentage of humus	Percentage of humus in normal soils nearby	Remarks
0—6 in.	0·43	9·72	0·12	0·82	
6 in.—1 ft.	0·52	10·01	0·15	0·70	
1—2 ft.	0·28	9·85	0·04	0·52	The capillary rise observed for 300 minutes did not show any rise in any of these samples.
2—3 ft.	0·33	10·08	0·32	0·32	
3—4 ft.	0·22	9·87	0·36	...	

The results given in Table VI show that leaching reduced soluble salt contents but increased the pH values to an appreciable extent. The humus contents were considerably reduced in leached soils. Thus these C type of alkali soils on leaching get strongly alkaline which require chemical treatments for their improvement which are described later.

Role of local sugarcane (Pundia) in reclamation

Field observations were made after the crop had established itself in the field. Observations were taken at each graded growth, and demarcations were carefully made where there was a uniformly good crop in several rows followed by appreciable change from good to medium and further on to patches with inferior growth. This will be clear from Plate IX, figs. 1 and 2 taken in a graded growth of sugarcane plot.

This was done in the same soil type (deep soil) as near as possible and under identical conditions of preparatory tillage, manuring, irrigation and after care. Soil samples were taken from the first foot pounded in wooden mortar, passed through 1 m.m. sieve and used for experimental tests.

The following tests were carried out:

(1) Capillary rise in five hours.
(2) pH values.
(3) Salt content by Dionic Water Tester.

The idea in carrying out these tests was to note which factor had a dominant effect on the growth of crops.

Study of sugarcane

The cultivators on Deccan canals grow Sugarcane known as Pundia, which is a thick cane, fairly rich in sucrose and is a good yielder, but the main drawback is its sensitivity to even slight salinity or alkalinity. Before other varieties were introduced, this was exclusively planted by cultivators as it is a very soft cane and can be crushed with bullock crushers. Evidently one had to wait for a long time after drainage to make soil conditions ideal for growing successful crops. The study of the resistance of this local cane was made in the Experimental Salt Area. Nearly 250 representative soil samples one or more from each plot was taken from the surface 12 in. depth, because it was noticed that the roots at this stage of the crop penetrated almost to 12 in. depth, in the soil. Plate IX, fig. 3 illustrates the root system taken from good and inferior growths of sugarcane of Pundia and CO 290 varieties.

After getting the samples of the required type, soil extracts were prepared and pH values were found out by the colorimetric method (Clark and Lubs) using 1 to 10 soil water ratio. The total soluble salts were also found out by the Dionic Water Tester and capillary rise was noted for five hours. The results showed a variation in pH values ranging from 7·3 to 9·0 with varying capillary rise and salt contents. Table VII gives the mean results of each grouping.

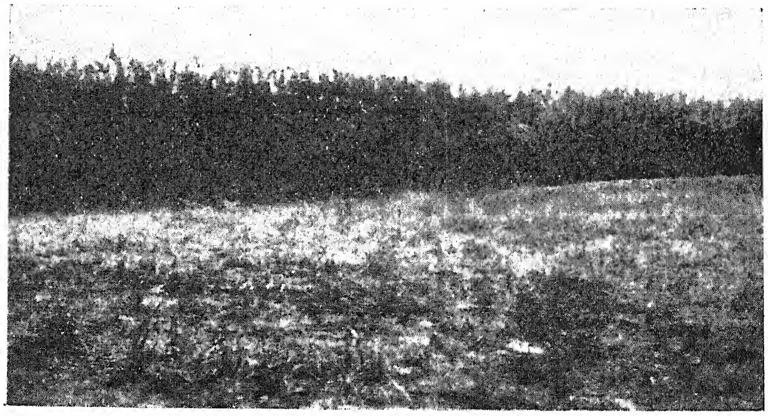

FIG. 1. Graded growth of sugarcane in mixed Saline soils

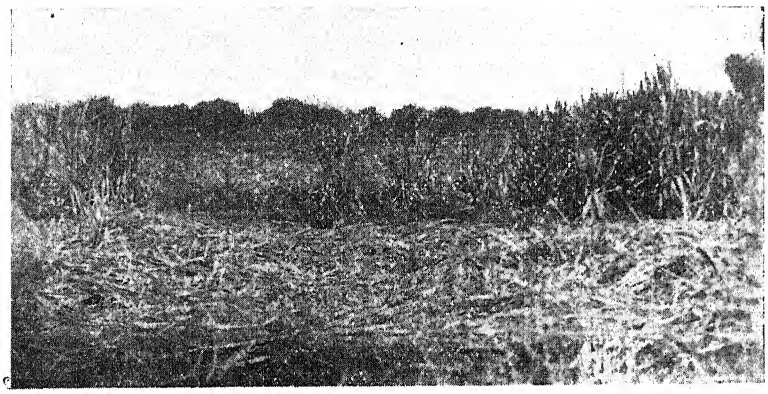

FIG. 2. Graded growth of sugarcane in strong alkali soils

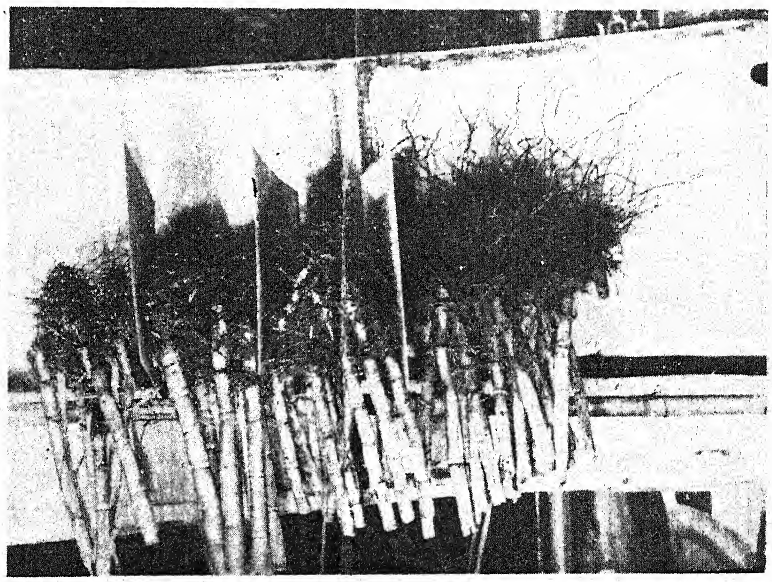

FIG. 3. Root system of sugarcane in alkali soils. (1) Co. 290, good root system ; (2) Co. 290, inferior root system ; (3) Pundia, good root system (4) Pundia, inferior root system

TABLE VII

Average pH values and capillary rise and soluble salts of soil samples

Serial No.	pH values	Capillary rise in cm.	Percentage of soluble salts by conductivity	Remarks
1	7·30	14·00	0·33	Average of 3 tests
2	7·4	14·70	0·29	„ 3 „
3	7·5	12·95	0·25	„ 12 „
4	7·6	11·70	0·31	„ 16 „
5	7·7	13·30	0·34	„ 3 „
6	7·8	13·75	0·27	„ 30 „
7	7·9	13·80	0·25	„ 3 „
8	8·0	12·40	0·25	„ 25 „
9	8·1	13·55	0·25	„ 16 „
10	8·2	14·20	0·30	„ 38 „
11	8·3	12·40	0·36	„ 16 „
12	8·4	8·50	0·30	„ 22 „
13	8·5	6·60	0·45	„ 8 „
14	8·6	7·20	0·32	„ 14 „
15	8·7	2·50	0·37	„ 12 „
16	8·8	2·20	0·42	„ 11 „
17	8·9	0·70	0·46	„ 4 „
18	9·0	0·00	0·38	„ 16 „
				Total 242 tests

The results given in Table VII are reproduced in Fig. 2. The figure clearly shows the close relation between *p*H values and physical conditions of the soil. The soil tilth is very good as indicated by the capillary rise varying from about 7·0 140 cm. and as indicated by *p*H up to the value of 8·6 beyond which it is bad being *nil* at *p*H 9·0.

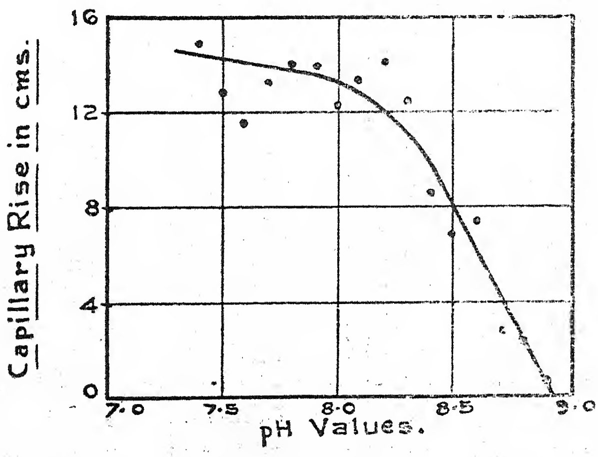

FIG. 2. Capillary rise and *p*H values of plots of Baramati Experimental Salt Area

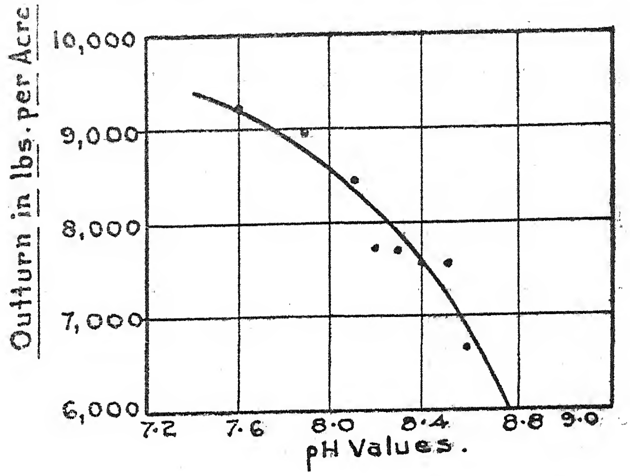

FIG. 3. Outturn of *pundia* cane in various plots of Baramati Experimental Salt Area with varying *p*H values

Fig. 3 shows the outturn and the average *p*H values of several plots in the Experimental Salt Area where Pundia Sugarcane was grown. It shows a marked reduction in outturn with increasing *p*H values, it being somewhere near 30 *pallas* (*7,500* lbs. of gul.) at 8·4 *p*H. This confirms observations of Fig. 2.

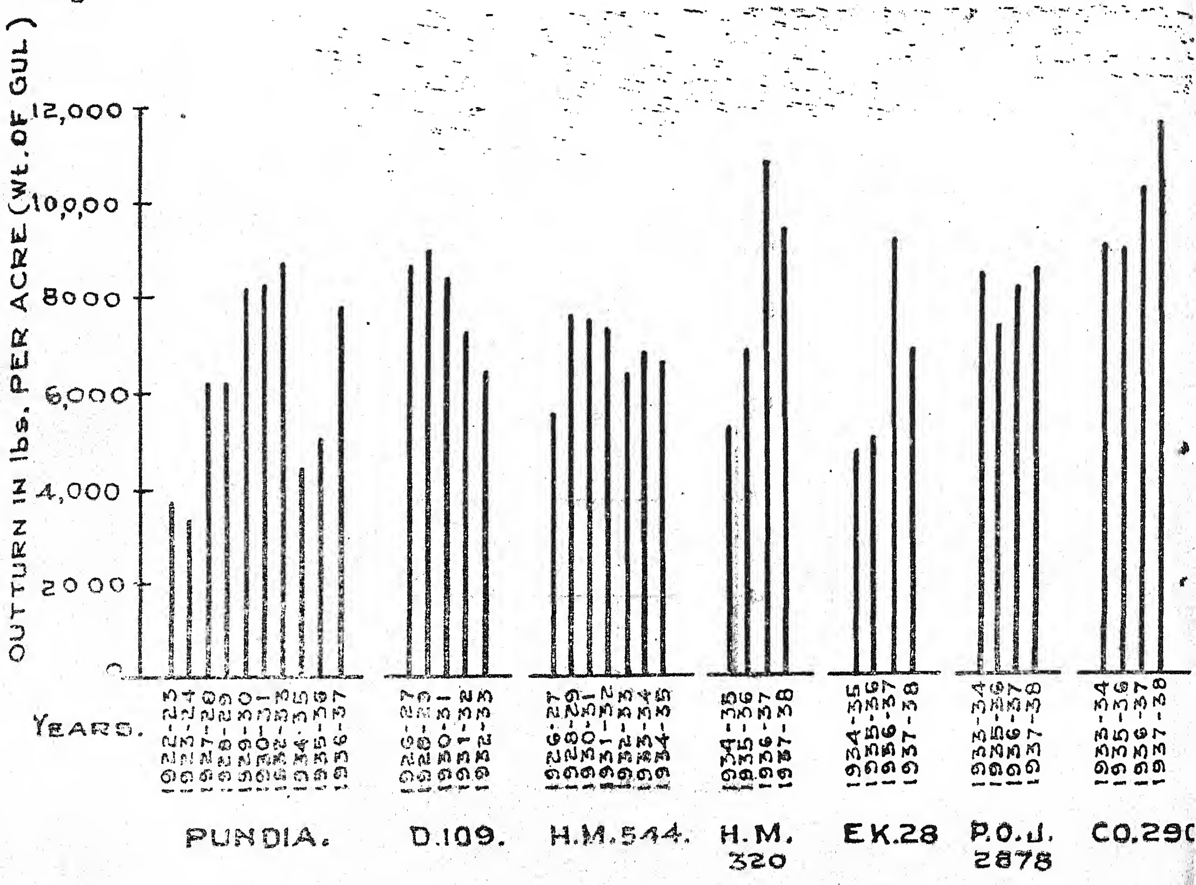

FIG. 4. Outtern of different varieties of sugarcane in Experimental Salt Area Baramati in different years.

Reclamation experiments with sugarcane varieties

Up to 1925-26 Pundia alone (a local cane) was grown in salt lands. Since 1926-27 several varieties of cane newly introduced into the canal tracts have been under test as regards their resistance to salts and sodiumisation, but little progress was made until 1932-33. Of the varieties tried only D 109 and HM 544 continued to give yields nearly as good as Pundia. But even these were noticed to deteriorate in course of time. D 109 showed tendency to lodge and put up crocked canes troublesome to crush. HM 544 produced inferior gul. The varieties as a rule did not then tiller well and germination was affected by the impervious soil which did not dry up soon. Dry plantation and light watering had, therefore, to be resorted to in some cases. Cane was rotated with robust fodder crops such as *nilwa, jowar and dhaincha* (*Sesbania aculeata*) to provide green manure previous to the planting of cane. Cotton was selected to grow after cane as it yielded well and improved the soil. The early cane varieties tried received bulky manures at the rate of 10,000 lb. per acre and in addition a dose of 150 lb. of nitrogen was given as top dressings in form of ammonium sulphate and oil cakes.

POJ 2878 and HM 320 succeeded well and gave much higher return than Pundia. After 1932-33, CO 290 variety was intoduced. This was found to be very resistant to salt (1 to 1·5 per cent salts) and sodiumised soil with *p*H 9·96. POJ 2878 stood next in tolerance to alkalinity. It stood up to 9·7 *p*H, but not salts exceeding 0·5 per cent. POJ 2883 and EK 28 were comparatively very sensitive.

The performance of different varieties tried in salt lands from 1922-23 to 1932-33, will be clear by reference to Fig. 4, which gives outturn year after year. The results indicate how certain varieties deteriorated in course of time while others not only maintained their yields but gave increasing yields.

The system of randomisation and replications which being capable of statistical treatment gives decisive results was introduced since 1933-34. The results are summarised in Table VIII.

TABLE VIII

Results of varietal trials

Serial No.	Description	Pundia	HM320	EK 28	POJ 2883	POJ 2878	CO 290	Significance figure
1	Alkaline soil *p*H 9·2 (lower -area), 1934-35	11·01	14·13	18·99	24·28	25·99	Not tried	9·98
2	Mixed Saline soils (lower area) *p*H 8·5 to 9·0·6 replicates 1935-36	20·88	36·36	23·00	35·65	36·97	51·88	9·16
3	Middle area, mixed saline soils 6 Replicates, 1935-36	32·36	34·70	29·08	34·84	35·38	54·41	8·32
4	Lower area 1936-37, 5 replicates	38·83	48·90	46·84	47·44	48·34	71·73	16·04
5	Middle area, 6 replicates, 1936-37	25·45	38·07	35·35	35·05	27·57	51·41	10·36
6	Lower area, 1937-38 . .	22·78	38·41	37·93	37·16	47·30	56·99	10·16
7	Middle area, alkali soil, 1937-38	11·73	25·94	20·04	19·77	24·00	40·13	8·25

The results show that CO 290 has given highly significant results all through. POJ 2878, HM 320 and POJ 2883 have given in four out of seven cases examined.

During 1938-39, several new varieties were tried in alkali soil (C type) of the description as given in Table IX.

TABLE IX

Depth of soil	pH values by electrical method	Capillary rise in 5 hours		Percentage of soluble salts
		Distilled water	Normal Nacl solution	
0—6 in.	9·92	0·50	1·60	0·19
6—12 in.	9·88	0·50	1·70	0·20
1—2 ft.	9·72	0·55	1·30	0·32
3—4 ft.	9·00	0·65	2·90	0·24
6—7 ft.	8·80	2·70	4·05	0·23

The results as given in Table IX show that though the soluble salts were low, the soil was highly alkaline. Cane was planted on 5 January, 1938. Partial earthing up was done in July, while complete earthing up was given by the middle of August. After these operations, the growth in the case of CO 290 and CO 419 made good progress.

The outturn of different varieties are tabulated in Table X.

TABLE X

Results of outturns (converted into *pallas*. 240 lb. = 1 *palla*.)

Cane variety	Outturn in *pallas* per acre				Total	Mean
	Blocks					
	1	2	3	4		
CO 360	27·4	33·3	21·5	26·0	108·2	27·0
CO 419	56·8	45·0	18·5	30·5	150·8	37·7
CO 408	37·3	27·2	18·6	25·7	108·8	27·2
CO 290	39·6	45·2	39·4	37·0	161·2	40·3
CO 417	33·3	29·7	29·1	37·4	129·5	32·4
POJ 2878	22·5	22·7	11·7	19·2	76·1	19·0
TOTAL	216·9	203·1	138·8	175·8	734·6	..
MEAN	36·0	33·8	23·1	29·3	G.M.	30·6

Significance figure 9·95

From the data as indicated in Table X it will be seen that CO 290, CO 419 and CO 417 are significantly better than POJ 2878 ; CO 290 stands out the best followed by CO 419.

During 1940-41, the experiment was continued in highly alkaline soil of the description as given in Table XI.

TABLE XI

Soil tests of C2 type under experimentation

Soil depth	Replaceable Na+K X-Milli-equivalent percentage	Replaceable Mg.	Replaceable calcium	Total bases	pH values		Percentage of soluble salt	Ratio of Replaceable Ca to Na and K
					In Water	In N-KCI solution		
0—6 in.	13·196	7·54	18·36	38·568	10·02	7·56	0.950	1·39
6—12 in.	15·228	8·44	7·14	30·81	10·12	8·82	1·200	0·47
18—24 in.	0·048	9·82	17·34	33·208	10·28	7·82	0·600	2·87
24—36 in.	13·068	12·88	10·71	36·658	10·54	8·32	0·900	0·82

The preparatory tillage was given by means of Gallows Plough. Two ploughings were given. The land was divided into deep ridges and furrows by a heavy ridger. The area was then divided into small sub-plots of one *guntha* and alround shallow drains were opened out. These shallow gutters were joined to main drains. Farmyard manure was spread in the furrows at the rate of 15,000 lb. A basal dose of three tons of gypsum was also given at this stage and spread in furrows. The soil was then thoroughly stirred with pickaxes. On this a layer of *pachat* was spread at the rate of 10 tons per acre. The V-shaped furrow thus turned into a flat shape. *Dhaincha* was lightly broadcast at the rate of 30 lb. per acre. Dry planting was resorted to during August 1940. Seed rate was increased to 12,000 setts per acre and light irrigation was given. Due to light showers good germination was secured. *Dhaincha* was burried in again with *kudali* (pickaxes) after two months by taking little soil from the ridge portion.

After 3½ months the *pachat* layer was completely rotted and it added organic manure to the soil. Partial earthing up was given after five months and complete earthing up was given when the canes developed three internodes. Very light irrigation was given throughout ; 225 lb. of Nitrogen was given by the time of earthing. This was the first successful crop in such highly alkaline soil.

Result of cane outturns in saline alkali (highly alkali) soils

Date of plantation : 20 August 1940
Adsali cane.
Date of Harvest : 10 January 1942

TABLE XII

Cane outturns in highly alkali soils

Name of variety	Outturns of cane in tons per acre	Difference from CO 419	Brix of juice	Percentage of sucrose	Remarks
CO 419.	35·88	*Nil*	20·70	15·89	The Experiment was conducted with 5 replicates
CO 417	54·93	19·05	20·14	16·61	
CO 411	44·52	8·64	20·82	16·44	
CO 426	48·45	12·57	17·82	14·04	

Significance figure 15·06

Out of CO varieties CO 417 gives significantly greater yield than CO 419 variety. CO 426 is a runner up. CO 417 is a promising cane for saline alkali soils, while CO 419 variety, which gives good results in alkali soils up to 9·5 pH, gave poor results in strong alkali soils. Plate X, figures 1 and 2 shows the growth of different cane varieties after maturity.

Bulky manure experiment in mixed saline soils

As stated above early experiments were laid out with local cane Pundia which was a favourite cane with the cultivators.

The Experiments were continued in four blocks serving as replicates with the following treatments randomised in each block.

(1) 10,000 lb. of Farmyard manure
(2) 20,000 ,, ,, ,,
(3) 30,000 ,, ,, ,,
(4) 40,000 ,, ,, ,,
(5) 50,000 ,, ,, ,,

There were 20 subplots measuring two *gunthas* each with a ring alround. The *p*H values of these plots were from 8·5 to 9·0 (B type), while average salt contents were 0·5 per cent. As stated above the local cane Pundia was tried from 1933 to 1935 and the tolerance study carried out by the writer thereafter threw much light on the crop growth and other varieties were immediately introduced.

Planting was done on sides of furrows and with hands (instead of pressing with legs) to keep them in the first two inches only so as to protect the eyebuds from excessive moisture in the initial stages. This method secured good and uniform germination. Artificial top dressing was given in addition to farmyard manure. The artificial manure was given as under :

Time	Manure	Dose
First dose $1\frac{1}{2}$ months after planting .	Ammonium sulphate and groundnut Cake.	25 lb.per acre 25 ,, ,, ,,
Second dose 2 months ,, ,, . .	Ammonium sulphate	25 ,, ,, ,,
Third dose 4 months ,, ,, . .	Groundnut cake	25 ,, ,, ,,
Fourth dose 6 to 7 months ,, . .	Castor Cake	50 ,, ,, ,,

About six weedings were given, while 36 irrigations were given in all. Partial earthing up and full earthing up were given after four months and $6\frac{1}{2}$ to 7 months of planting. The most important point in irrigation was to give slow irrigation and see that there was thorough soaking of the soil and no free water was allowed to be kept in the furrows. The quantity of water given in such soils was 100 acre inches.

The results of outturns are given in Table XIII.

TABLE XIII

The results of bulky manure experiments

Serial No.	Description	Treatments					Significance figure.
		10 carts =10,000 lb	20 carts	3 0 carts	40 carts	50 carts	
1	Lower area *p*H 8·10 (Pundia 1933-34)	38·44	59·03	54·35	69·42	79·09	12·42
2	Middle area *p*H 8·0 (Pundia 1934-35) .	20·67	37·46	40·20	45·57	51·28	6·96
3	Middle area *p*H 8·5 (Pundia 1934-35) .	22·87	27·97	36·60	38·54	26·63	4·57
4	Lower area *p*H 9·0 (POJ 2878, sugarcane variety 1935-36)	39 23	36·09	41·72	38·86	41·71	13·20
5	Middle area *p*H 9·0 (variety 2878 1936-37)	32·89	38·66	41·17	35·83	30·11	19·5

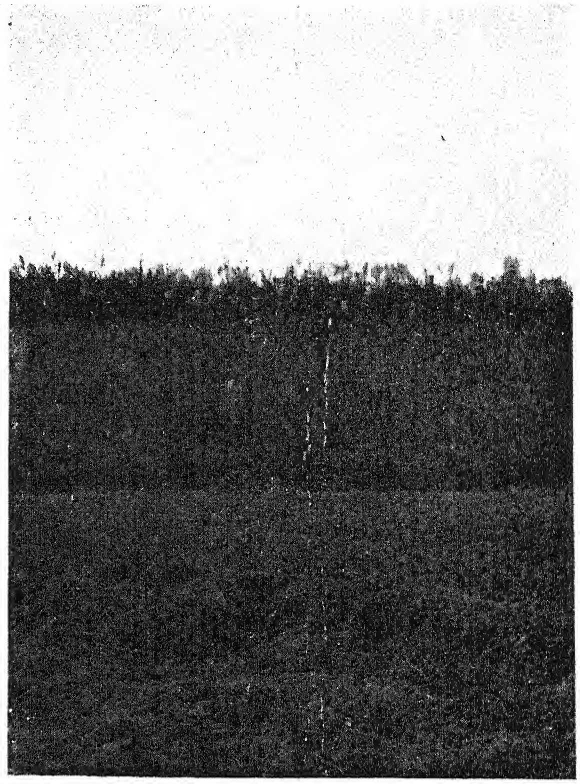

FIG. 1. Bumper crop of CO 290 variety of sugarcane after reclamation

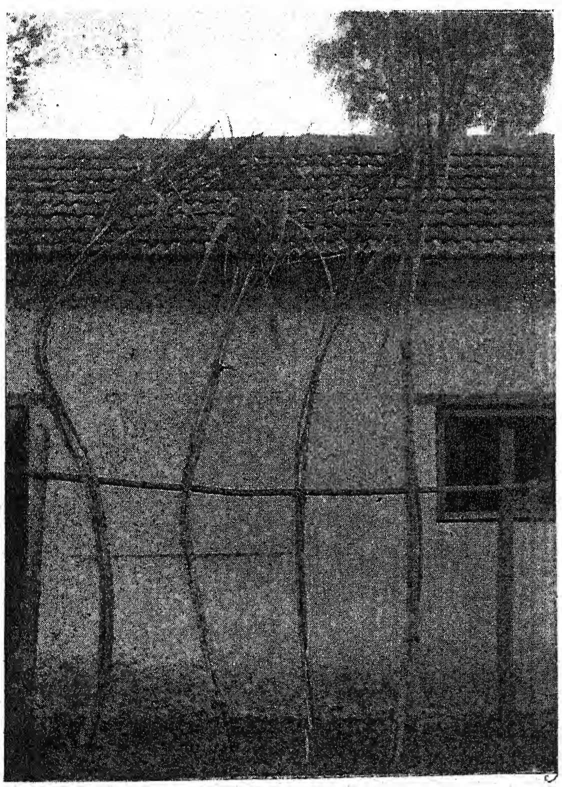

FIG. 2. Stand of different CO varieties as *adsali* crop in strong alkali soil. Left to right (1) CO 426, (2) CO 411, (3) CO 419, (4) CO 417

FIG. 1. Normal crop of *shalu jowar* crop two years after various treatments

FIG. 2. A bumper crop of *dhaincha* green manure in upper Area of Baramati after leaching

On referring to Table XIII, it will be seen that treatment variation was significant only in two cases where the soil was of mixed saline type with *p*H 8·5 to 9·0. In the rest of the cases the treatment variation was not significant as the soil was of C_1 type and farmyard manure alone failed to cause any response.

The results on the whole, whether statistically significant or not are very instructive and, after consideration of all cases lead to the conclusion that farmyard manure appears to have slightly increasing effects with 10 to 30 carts.

Subsequent doses of 40 to 50 cartloads increased the outturn in good soil plots but reduced it in stiff soil plots, due to want of proper aeration necessary for humification. The results on the whole show that in stiff alkali soil (*p*H about 9·0), farmyard manure alone is not significantly effective. Farmyard manure may be used to a maximum quantity of 30 cartloads per acre as may be justifiable economically but it is wasteful to use farmyard manure in excess of this quantity.

During 1938-39, CO 290 variety was planted on 15 March 1938 and irrigations were given as usual. Treatment besides farmyard manure was given to see the relative efficacy of each of the bulky manures.

Treatment	*Dose per acre*
(1) **Farmyard manure**	**30,000 lb.**
(2) **Sheep manure**	**15,000 lb.**
(3) **Blank or no treatment**	

There were 20 subplots, measuring two *gunthas* each. The *p*H values of these plots were on an average above 8·5 while the salt contents were 1·1 per cent.

The results of outturn were as under given in Table XIV.

TABLE XIV

The relative efficacy of bulky manures

Treatment	Block 1	Block 2	Block 3	Block 4	Mean
Blank or no treatment	37·5	34·2	31·4	38·2	35·3
Sheep manure	41·2	40·6	35·3	41·0	39·5
Farmyard manure	40·7	46·3	41·4	48·0	44·1
Mean	39·8	40·4	36·0	42·0	G.M.
Significant figure	3·41	..	..	..	39·6

The results show that farmyard manure stands first in the experiment.

Experiments with chemical fertilizers

In slightly still stiffer soils experiments were laid out with different doses of gypsum varying from 1 to 3 tons per acre. CO 290 variety of sugarcane was tried. The method of planting, weeding, and irrigation was just the same as described in the previous sugarcane experiments with bulky manures. Gypsum was applied in furrows along with farmyard manure.

For statistical treatment yields of cane in tons per acre were taken into account in all cases as this excluded errors due to crushing, etc. The subplots were of 3½ *gunthas*, size excluding ring of 1½ *gunthas*, the net experimental subplot was 2 *gunthas*. The experiments with doses of gypsum from 1 to 3 tons per acre were laid out in randomised treatments in replicated plots. The results were examined statistically. The area being under reclamation soil variation was rapid and so random errors due to soil difference were high. Still five experiments out of eight gave significant results. These are summarised in Table XV.

TABLE XV

Yield of sugarcane with varying doses of gypsum and other fertilizers

Treatments	Old series					Treatment per acre in addition to basal dose of farmyard manure	New series			Remarks
	1933-34	1933-34	1934-35	1934-35	1934-35		CO 419 variety of sugarcane			
	Lower area, plot Nos. 18, 23, 24 (CO 290 variety)	Lower area plot Nos. 19 and 19A (Pundia)	Lower area, plot Nos. 27, 28 (CO 290 variety)	Lower area, plots 5, (a), 6, 7 (CO 290 variety)	Middle area, plots 84 to 86, 88 and 89 (CO290 variety)		1938-39	1939·40	1940·41	
Per acre	(20 cart loads) farmyard manure	(10 cart loads) farmyard manure	(20 cart loads) farmyard manure	(10 cart loads) farmyard manure	(10 carts) farmyard manure					
	Mean yields per acre (tons of canes)						Mean yield per acre in tons			
Blank	30·45	31·95	24·74	21·66	23·46	Blank	30·70	46·70	44·30	In new series, doses were fixed on basis of equal cost
One ton gypsum	44·90	39·26	27·99	30·87	28·16	Gypsum (8,400 lb).	33·8	51·90	57·9	
2 tons gypsum	48·56	44·45	29·80	37·77	34·55	Calcium carbonate (crushed 8,400 lb.)	35·7	38·30	40·0	
3 tons gypsum	51·28	52·33	33·35	44·97	48·85	Sulphur (½ ton)	33·9	57·50	48·3	
Significance figure	3·50	7·12	4·52	7·94	10·62	....	..	..	..	

It is seen from Table XV that the outturn of cane increased with the doses of gypsum and that the yields from 2 to 3 tons treatments were always significant as compared to 'No Treatment'.

The outturn during the years 1938-39 to 1940-41, with other treatments besides gypsum show that gypsum and sulphur gave alternately good results.

Soil Improvement in presence of rotational crops (Seasonal)

Research in the laboratory and small plot experiments had shown that stiffness of the soils in the Experimental Salt Lands at Baramati on the Nira Left Bank Canal was due to the presence of sodium clay and for the recovery of soil tilth it was necessary to convert sodium clay into calcium clay by base replacement. Farmyard manure alone, though very essential, was not of much use in this respect. Several cane varieties, bulky and chemical manures were tried on a large scale in stiff soil plots in presence of sugarcane crop to determine the dose adequate for such soils. This experiment was conducted in presence of seasonal crops to see the effect of intermittent irrigation on the alkali soil.

Experiments

Several soil improvers as detailed below were applied in plots 5b and 5c in the salt lands where the soil was very stiff and no crop could grow hitherto. The following analytical data clearly show the nature of the soil in 1937 :

Serial No.	Test	Percentage	Remarks
1	Total soluble salts	0·47	Alkali soil of C_1 type
2	*p*H value	9·16	
3	Capillary rise in distilled water in five hours	2·50 cm.	
4	Capillary rise in N Nacl solution	17·00 ,,	

The improvers were either used singly or in combination in small plots of 16½ ft. × 16½ ft.

The whole experiment was subdivided into four sub-experiments, *viz.*:

1. Use of calcium salts, *viz.*:
   (1) Calcium carbonate
   (2) Calcium sulphate (local produce 86 per cent purity)
   (3) Calcium carbonate
2. Use of sulphur and sheep manure used singly
3. Use of sulphur in combination with calcium salts, and farmyard manure
4. Use of sheep manure in combination with calcium salts and sulphur
5. Use of all improvers such as :
   (1) Sheep manure
   (2) Farmyard Manure
   (3) Compost
   (4) Calcium sulphate
   (5) Oil cake
   (6) Molasses

The experiment was continued for three years from 1937 to 1940. The main features were as shown below :

(1) The subplots (beds), 132 in number, were prepared in 1937. Soil samples were collected from these plots in January, 1938. Treatments were added in the month of February, 1938, and the crops of *Nilwa* and *Khapla* were sown in the months of July, 1938, and November, 1938, respectively, and harvested in October, 1938, and March, 1939, respectively.

(2) During the following year in May, 1939, the different treatments were repeated. Doses in each treatment are shown in the statement below.

A crop of *shalu* was taken, soil samples were collected before the addition of treatment and after the harvest of the crop.

Results

The outturns show increased yields with the following improvers used singly or in combination.

Serial No.	Treatments	Treatment yielding highest returns
(1)	Calcium salts	$CaSo^4$
(2)	Sulphur in combination with calcium salts	$CaCo_3$ + sulphur
(3)	Sheep manure + calcium salts	$CaCl^2$ + sheep manure
(4)	All improvers	Farmyard manure

The soil data for the promising treatment is summarised below in Table XVI.

TABLE XVI

Soil data for promising treatments

Serial No.	Treatment	1938-39				1939-40			
		Before addition of treatments		After harvest of *khapla*		Before addition of treatment		After harvest of *Shalu*	
		*p*H	Percentage of salt	*p*H	Percentage of salt	*p*H	Percentage of salt	*p*H	Percentage of salt
(1)	$CaSo_4$	8·31	0·49	8·35	0·51	9·60	0·35	7·82	0·37
(2)	$CaCo_1$ + sulphur	8·49	0·64	9·23	0·34	9·53	0·33	8·00	0·25
(3)	$CaCl_2$ + sheep manure	8·87	0·23	8·47	0·46	9·76	0·30	8·64	0·25
(4)	Farmyard manure	8·79	0·49	9·26	0·28	9·64	0·32	8·20	0·20

The application of the doses twice during the two season had caused lowering of *p*H value, and salt content and improvement of soil tilth, which had resulted in a normal growth of *shalu jowar* as seen in Plate XI, fig 1. It was for the first time that normal crops were grown in these plots.

Results

In 1940-41 a second crop of *shalu jowar* was grown in the same area to note the residual effect of these treatments on soil as judged by crop growth.

Results of outturn of *shalu jowar* for both the years are given for comparison in Table XVII.

Table XVII

Yields of *shalu jowar* crops in 5b, 5c (1) in 1939-40, *i.e.* after the addition of soil improvers and (2) in 1940-41 *i.e.* after one year.

Experiment No.	Treatment	Doses based on equal cost Rs. 75 per acre	Shalu jowar: Crop with grains in 1939-40 in lb.	Shalu jowar: Crop with grains in 1940-41 in lb.	Increase or decrease in yields in lb.
	Single series of calcium salts, sulphur and sheep manure				
I	Calcium chloride	½ ton	51·2	40·0	—11·2
	,, sulphate	3 tons	56·6	52·3	—4.3
	,, carbonate	2 ,,	49·0	51·0	+2·0
	Sulphur	¼ ton	53·3	56·3	+3·0
	Sheep manure	7½ tons	52·1	42·1	—10·0
	Blank		42·0	31·0	—11·0
		Total	304·2	272·7	
II	*Calcium salts in combination with sulphur*				
	(A) (B)	(A) (B)			
	Sulphur + $CaSo_4$	¼ + ½ ton	44·0	59·3	+15·3
	,, + $CaCo_3$	¼ + 1 ton	63·0	36·6	—26·4
	,, + $CaCl_2$	¼ + ¼ ton	58·0	68·3	+10·3
	,, + farmyard manure	¼ + 6 tons	44·0	47·0	+3·0
	Sulphur	¼ ton	53·5	40·3	—13·0
	Blank	...	45·3	46·3	+1·0
		Total	307·6	297·8	
III	*Calcium salts in combination with sheep manure*				
	(A) (B)	(A) (B)			
	Sheep manure + $CaSo_4$	3¾ + 1½ tons	61·0	73·1	+12·1
	Sheep manure + $CaCo_3$	3¾ + 1 tons	55·6	54·1	—1·5
	Sheep manure + CaC_2	3¾ + ½ tons	55·0	58·5	+11·3
	,, ,, + sulphur	3¾ + ½ tons	55·6	58·8	+3·0
	Blank		54·6	48·5	—6·1
		Total	281·8	300·6	
IV	*Single series of all improvers*				
	Sheep manure	7½ tons	45·8	45·7	—0·1
	Molasses	55 maunds	39·9	44·3	+4·4
	Farmyard manure	12 maunds	45·3	42·0	—3·3
	Compost	12 tons	31·7	30·3	—1·4
	Calcium sulphate	3 tons	42·2	34·7	—7·5
	Oil cake	1760 lb.	31·2	30·7	—0·5
	Blank		40·0	36·5	—3·5
		Total	276·1	264·2	

Weight of shalu jowar is per plot of 16½ ft. × 16½ ft.

Experiment I

It will be seen that excepting sulphur which gave slightly higher results, gypsum has retained its place.

Experiment II 24

Calcium chloride in combination with sulphur gave the highest yield instead of calcium carbonate and sulphur, as in the previous year. Next to calcium chloride+sulphur, stood calcium sulphate+sulphur. Calcium carbonate+sulphur although topped the list last year, gave the least yield during this year.

Experiment III

Calcium sulphate + sheep manure was the best treatment for both the years.

Experiment IV

Sheep manure stood first for both the years. The results obtained with farmyard manure are only slightly lower than those with sheep manure.

To summarise, the results are on the whole much in favour of calcium sulphate as hitherto. Slight effect of sulphur with time was seen in Experiment I, but in Experiment II considerable lowering of the yield was observed.

In the case of Molasses an increase in yield was seen one year after the addition. Sheep manure although promising can be replaced by farmyard manure when the former is not available.

Trial of Rotational Crops during and after reclamation

It is seen that sugarcane is the principal crop in the Deccan Canals and is remunerative both to the cultivators and the state. Hence after studying the different suitable varieties the next important item to study was the suitable rotational crops to sugarcane. Different rotational crops of this locality are :

Serial No.	Name of crop	Kind of crop	Time of sowing
1	*Nilwa jowar*	Fodder crop, seasonal crop of four months	Monsoon ; June
2	*Shalu jowar*	Fodder crop of four months	15 September
3	Cotton	Fibre crop of four months	15 April

Tolerance of some of these crops was studied in detail by taking a number of soil samples up to 12 in depth at each graded growth of crop, pH values (electrometric), soluble salts and capillary rise were found out for soils at each graded growth. The results are interesting and are set out in Fig. 5. From this it will be seen that the order of tolerance of these crops is as under :

(1) *Nilwa*, (2) Cotton and *shalu*

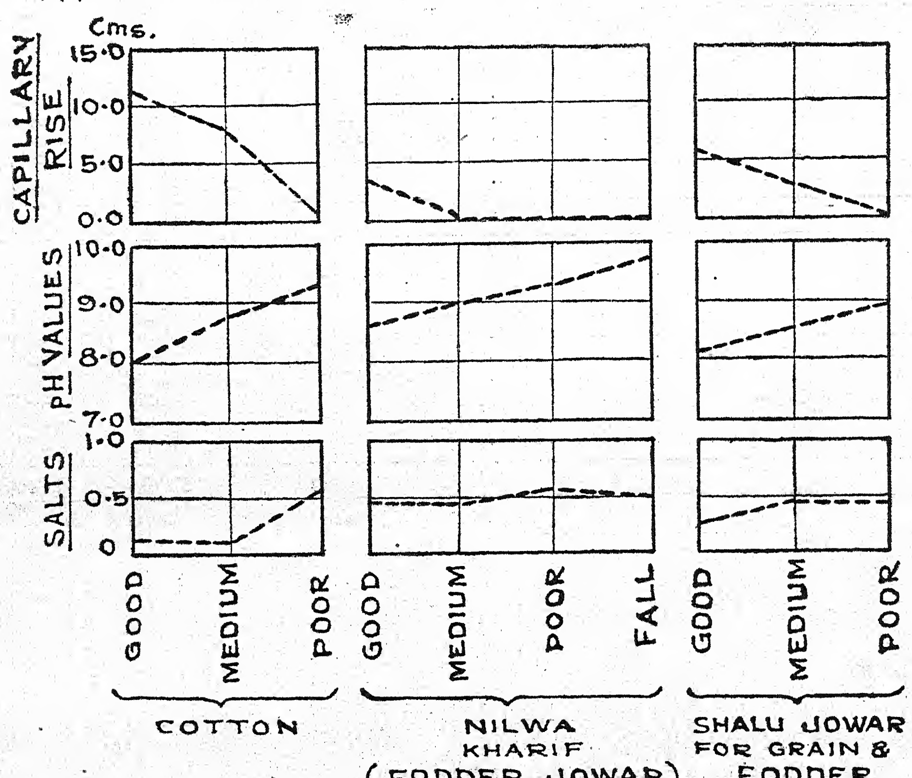

FIG. 5. The relative resistance of various crops to saline or alkaline conditions

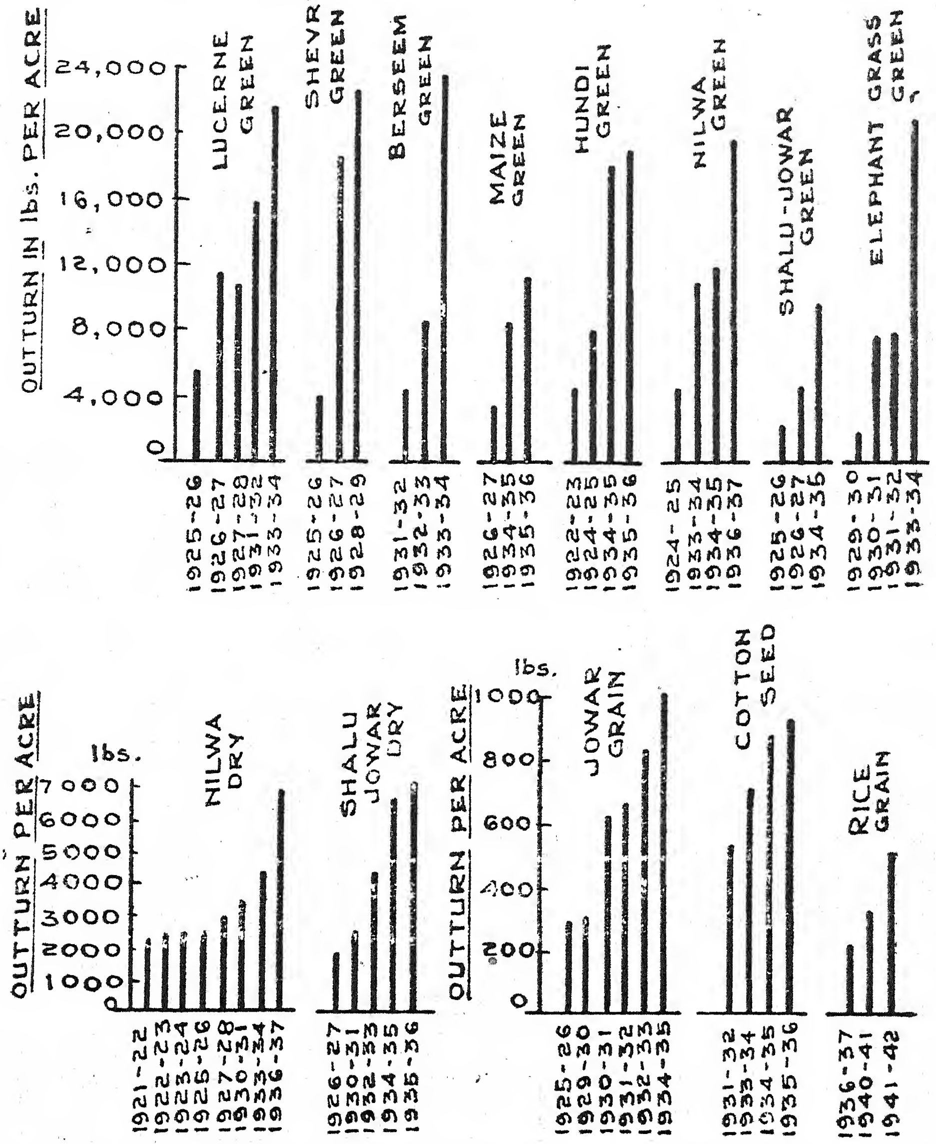

FIG. 6. Outturn of fodder, grain and other crops in Baramati Experimental Salt Area during different years

Sowing of fodder crops was done by one shallow ploughing followed by harrowing. Higher seed rate was used as a rule; 25 per cent more seed rate gave good results. Cotton was dibbled after harvesting of sugarcane without any preparation. This crop improved the soil by its deep root system and gave a fairly good yield on account of the residual effect of previous manure given to sugarcane crop.

The results of different fodder crops year after year are summarised in Fig. 5 which shows that increasing yields were obtained year after year, indicating the progress of reclamation. The results show the part played by rotational crops in the process of reclamation.

Amongst other perennial crops tried, *shevari* gave promising and quick results. This is the most tolerant of all crops tried so far and resists salt up to 1 to 1·5 per cent and can grow well in soil up to 9·5 to 10·0 *p*H. Lucerne comes next to it.

The comparative outturns are given in the statement and conforms the statement of its tolerance.

Berseem fodder

This is a valuable fodder and gives good outturns. The crop grows in soils up to pH value of 9·5 but it fails with further increase of pH. It is however, sensitive to salt and it suffered badly at 0·50 per cent salt contents.

Maize and hundi fodder

These are also very valuable fodders but are sensitive and are recommended for trial in soils where *nilwa* (fodder *jowar*) thrives very well.

Paddy

This is a useful crop for mixed saline soils. It thrives well up to 0·62 per cent salts and pH up to 9·0 ; with higher salts, the growth is at once checked.

Trial of green manuring crops

The most improtant rotational cropping in sugarcane plantation is trial of green manures. Sunn green manures (*Croltalaria juncea*) is common on the Deccan Canals and grows luxuriantly. A very good crop weighs 30,000 lb. per acre. Its main drawback is its sensitivity to a little salinity or alkalinity. It is also frequently attacked by wilt and leaf diseases particularly in heavy deep soils. This was, therefore replaced by another green manuring plant *Sesbania aculeata*, locally known as *dhaincha*. It is a hardy plant with green feathery leaves with pale yellow pea like flowers and very long pods. The cultivated plant has a thick tap root which opens up the soil and which has numerous big nodules. visible on uprooting the plant. In the field, typical spots were selected side by side where *Sunn* and *dhaincha* grew and weighments were taken at two spots just before green manuring with the following results :

Survey No.	Weight of green matter per acre in lb.		Remarks
128 Baramati	*Dhaincha* 18,000	*Sunn* 8,600	Average of four tests

The above results establish the superiority of *dhaincha* over *sunn* green manuring.

Soil tests with *dhaincha* with graded growth were done and the results are given in Table XVIII along with crop conditions.

TABLE XVIII

Soil tests with dhaincha with graded growth

Serial No.	Crop condition	Height of crop	Capillary rise in cm. in 5 hours	Percentage of salt	pH value	Anna valuation
1	Very good	7 ft. 6 in.	7·6	0·92	7·85	14 to 15
2	Good	5 ft. 0 in.	7·2	1·07	8·05	10 to 14
3	Medium	4 ft. 0 in.	9·33	1·70	7·93	6 to 10
4	Poor	2 ft. 0 in.	10·0	1·88	7·65	4 to 6

Salt contents

The growth is very good even with high salt contents of 1·07 per cent. It shows deterioration at 1·88 per cent.

Plate XI fig. 2 shows the excellent growth of *dhaincha* in Survey No. 348 of Baramati salt Lands. It was the first crop taken after flooding and leaching done in the previous season.

The green weight of *dhaincha*, noted at the time of harvest, was recorded for varying salt contet in soil to a depth of 6 in. The results are given in Table XIX.

TABLE XIX

The green weight of Dhaincha for varying salt contents

Name of crop and description	Salt content in 6 in. layer of soil	*p*H value of soil	Green weight of *dhaincha* per acre in lb.
Dhaincha	0·5	8·52	40,397
Seed rate 80 lb.	0·7	8·64	35,840
Sown on 10-6-39	0·9	9·00	15,360
Harvested on 19-8-39	1·5	8·80	8,960
Three irrigations were given in all	3·0	8·60	5,120

The results fully bear out results given in Table XVIII

SUMMARY

(1) Mixed saline soils after leaching of soluble salts were suitable for growing crops. Addition of bulky manures were, however, necessary. Experiment showed that 30,000 lb. of farmyard manure or compost gave very good results and high yields were obtained, from 40 to 50 tons of cane per acre. An *adsali* crop, in a fully reclaimed area of this type, gave 86 tons of cane for CO 290 variety and 92·8 tons for POJ 2878 sugarcane varieties. This indirectly showed the potential capacity of the soil after complete improvement. It will be seen that sugarcane plays an important part in the reclamation process.

(2) Alkali soils of C_1 type required addition of calcium fertilisers (or sulphur) in addition to farmyard manure. Repeated treatments for three years at the time of planting completely restored such soils to their normal conditions.

(3) Alkali soils of C_2 type required special treatment of farmyard manure with a basal dose of three tons of gypsum with a *pachat* (dry leaves of cane) layer over it, covered with soil. Simultaneous green manuring with *dhaincha* was also advantageous. Planting was done in the buffer layer and the sugarcane crop was planted in monsoon (July or August). This facilitated leaching of alkali salts. Proper humidity and special layer of *pachat* gave very good start and the growth was maintained till harvest. Hence *adsali* crop is recommended for improving highly alkaline soils.

(4) Several varieties were tried in lands in process of reclamation and most promising ones were CO 290, CO 419, CO 417, and POJ 2878. Amongst the rotational crops, *dhaincha* succeeded very well. This was followed by varietal canes. After harvest cotton was dibbled. This crop improved the soil on account of its deep root system. Moreover cotton being an alkali resistant crop gave normal outturn and fetched a good revenue.

(5) Amongst other perennial crops, *shevari* appeared to be very promising; lucerne was next to it.

(6) Paddy was suitable for mixed saline soils, but did not thrive in stiff alkali soils of the Deccan.

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STUDY OF MOVEMENT OF WATER AND SALTS IN SOILS AT THE AGRICULTURAL RESEARCH STATION, SAKRAND I

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Soil moisture is one of the predominating limiting factor in crop production. In most of the cases it is the lack of moisture which affects the yield of the crop, yet in some cases it is the excess of moisture which causes water logged conditions which is responsible not only for the failure of the crop but also for accumulation of salts on the surface. In irrigated tracts both these conditions are likely to occur.

With the release of Barrage water very vast areas are brought under irrigation and investigations were started to study the distribution of soil moisture and salts in the soil.

Object of this paper is to study the movement of soil moisture in salt free and saline soils in irrigated, cultivated fields, its ultimate distribution and the depth and the rapidity of its penetration when applied in different doses.

This part deals with the soil moisture.

The work has been carried out at the Agricultural Research Station, Sakrand, between 1930-1935.

Soils of Sind

The soils of Sind are alluvial in origin, deep loamy and calcareous. A striking characteristic of these soils is the lack of uniformity over any distance, the surface soil varying so considerably from spot to spot that it has become proverbial.

There is rarely a difference in colour between the soil and sub-soil except that due to moisture. The profile is undefined and structureless without any stratification. Sandy layers and layers of clay of various thickness alternate with each other and are often impregnated with various amounts of salts.

These soils are rich in potash and phosphoric acid content. The nitrogen content is low but the deficiency is counterbalanced by the high capacity of the soils for the fixation of atmospheric nitrogen and nitrification.

The soils are poor in organic matters with low water holding capacity. The sub-soil water is struck at the depth of 20 to 30 ft. on the left bank of Indus while at the right bank of Indus the sub-soil water level is much nearer to the surface.

A study of the soil moisture under field conditions is no doubt a very complicated problem when one has to remember how complex the soil itself is and how many are the forces acting upon the soil moisture. The study of the soil moisture which is both diverse and intricate is for the purpose of investigation resolved into the following items:

(a) Vertical movement of water as affected by different doses of water

(b) Movement of water in cropped fields, and

(c) Movement of water as affected by the presence of salts in the soil

(a) Vertical movement of water as affected by different doses of water

To study the vertical movement of water, samples of soils up to depth of 6 to 10 ft. were collected from fields and moisture was determined in each sample before the supply of water and five days after the supply.

Measured quantities of water were given to all the beds. Water was measured in a measuring tank and brought to beds in *pucca* irrigation channels.

The soil samples were collected from layers of 0-1 ft., 1-2 ft., 2-3 ft., 3-4 ft., 4-5 ft., and 5-6 ft., samples were collected from three spots in a bed of 1/40th of an acre to make one composite sample. All the necessary precautions were taken while collecting samples for moisture studies. These samples were brought to the laboratory in glass bottles with screw caps. Moisture was determined in sample by heating 25 grm. of soil on an oven at 100-110°C. and finding the loss. The loss is expressed as percentage on oven dry soil. Some of the typical results are given in Table I. The nature of surface soil was loamy and of sub-soil was sandy loam.

TABLE I

Percentage of moisture in soil samples

Dose	4 acre inches Before percentage of moisture	4 acre inches After percentage of moisture	8 acre inches Before percentage of moisture	8 acre inches After percentage of moisture	12 acre inches Before percentage of moisture	12 acre inches After percentage of moisture
0—1 ft.	3·8	15·2	1·7	19·2	11·8	23·3
1—2 ft.	4·2	12·6	3·0	16·4	8·7	25·7
2—3 ft.	5·2	7·6	6·9	20·5	8·8	27·5
3—4 ft.	5·4	4·0	9·4	11·6	7·5	31·7
4—5 ft.	6·7	7·7	15·7	17·0	12·5	24·8
5—6 ft.	16·3	16·0	4·6	4·6	18·6	22·8

Before—Sampling before addition of water

After—Samples taken five days after the last addition of water

Note.—4·0 acre inches of water were given in one dose. 8·0 acre inches were given in two doses of 4·0 in.; second dose was given after one day. 12·0 in. acre inches dose was given as under:

1st day—4·0 in.
2nd day—4·0 in.
5th day—4·0 in.

It will be seen from the figures given in Table I that within five days the downward movement of water extends to 3 and 4 ft. when the application of surface irrigation is 4 and 8 inches respectively. When the application is 12 in., the water goes beyond 6 ft.

(*b*) *Movement of moisture in cropped lands*

This has been studied with cotton crop. Movement of moisture in cotton fields has been studied from year to year commencing from 1931 to 1935. Cotton is sown by mid-May each year and the total quantity of water applied each year was as under:

(A) 46·5 in.
(B) 37·2 in.
(C) 31·0 in.
(D) 24·8 in.

Frequency of irrigation was as shown in Table II.

TABLE II

Frequency of irrigation

Treatment	Initial dose	Interval in days after the initial dose for subsequent irrigation and the dose of irrigation in inches								
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th
A	9/5 (8-0)	35 (4·5)	15 (4·5)	15 (4·5)	15 (4·5)	15 (4·5)	15 (4·0)	15 (4·0)	15 (4·0)	15 (4·0)
B	9/5 (8-0)	35 (3·4)	15 (3·4)	15 (3·2)	15 (3·2)	15 3·2)	15 (3·2)	15 (3·2)	15 (3·2)	15 (3·2)
C	9/5 (8-0)	35 (3·0)	15 (2·5)	15 (2·5)	15 (2·5)	15 (2·5)	15 (2·5)	15 (2·5)	15 (2·5)	15 (2·5)
D	9/5 (4-0)	35 (3·2)	15 (2·2)	15 (2·2)	15 (2·2)	15 (2·2)	15 (2·2)	15 (2·2)	15 (2·2)	15 (2·2)

Figures in brackets show the quantity of water applied in inches.

Samples of soil were collected at the following stages:

(1) Before the initial dose, *i.e.* 9/5.
(2) Five days after initial dose, *i.e.* 14/5.
(3) Before 1st irrigation, *i.e.* 16/6.
(4) Before 7th irrigation.
(5) After harvest in end December or beginning January.

Soil samples were collected from three spots in a bed to make a composite sample in layers of 0-1 ft., 1-2 ft., 2-3 ft., 3-4 ft., 4-5 ft., and 5-6 ft.

Surface soil was loamy in nature and sub-soil was sandy loam.

Some of the typical results obtained are indicated in Table III.

TABLE III

Movement of moisture in soil

Layer in ft.	At initial stage	Percentage of moisture						Total amount of water in in. added in form of irrigation
		After 5 days	Before 1st irrigation	Before 7th irrigation	At harvest time	Initial dose in in.		
0—1	5·8	21·0	7·2	3·5	3·5	8·0		46·5
0—1	..	19·5	8·5	4·0	2·5	8·0		31·0
0—1	4·0	19·5	8·0	4·0	3·0	4·0		24·8
1—2	4·0	19·0	8·0	4·5	2·2	8·0		46·5
1—2	..	18·0	9·2	6·0	2·0	8·0		31·0
1—2	6·5	16·5	9·8	5·0	4·0	4·0		24·8
2—3	5·8	15·2	7·3	3·4	2·2	8·0		46·5
2—3	..	15·8	8·5	3·0	7·0	8·0		31·0
2—3	1·5	16·5	9·2	5·2	4·0	4·0		24·8
3—4	5·5	11·5	9·5	4·0	3·2	8·0		46·5
3—4	..	8·5	10·5	10·0	3·0	8·0		31·0
3—4	2·5	13·2	11·0	4·5	4·0	4·0		24·8
4—5	10·0	11·5	16·0	7·8	9·5	8·0		46·5
4—5	..	8·8	11·0	12·0	3·5	8·0		31·0
4—5	12·0	8·8	12·6	10·4	5·2	4·0		24·8
5—6	16·5	18·0	19·5	12·8	10·8	8·0		46·5
5—6	..	15·2	18·0	2·5	8·0	8·0		31·0
5—6	21·2	19·0	20·8	20·8	11·2	4·0		24·8

It will be seen from the figures given in Table III that whatever be the initial dose, the amount of water left in the soil is nearly constant and that the loss of water is mostly within first three feet during the first 35 days. As the growth of the cotton plant during this period is negligible, the cotton plant cannot be requiring all the water that is lost. It can therefore be deduced that the loss is mostly by evaporation. Because the amount of water left in the soil is nearly constant in first three feet in plots receiving 4·0 in. and 8·0 in., it could be said that the initial irrigation has little bearing on the moisture content of the first three feet of soil and that the evaporation is in direct proportion to the dose of water given.

As the crop grows, loss of water is seen up to a depth of 6 ft. This loss is mostly due to transpiration as the fields are mostly shaded due to the growth of crop at this period. The amount of water left in the soil by mid-September up to the fifth foot in different irrigational treatments is nearly constant. This indicates that loss of water by transpiration and evaporation is in direct proportion to the amount of water added.

Samples of soil collected at harvest time about three months after the last irrigation in mid-October indicate that whatever be the amount of irrigation, the soil is left poorer in moisture at harvest as compared to their original state.

Since the first three feet of soil are depleted of its moisture during the first 35 days and since with the higher soaking dose there is more loss of water due to evaporation, it becomes clear that it is not necessary to give a heavy soaking dose before sowing in normal soils.

(c) *Relative movement of water in salt-free lands and saline soils*

The above was studied in cotton fields in saline and salt-free soils as well as in pots.

Plots of land in salt-free and saline soil were made into uniform size and measured amounts of water was left in each lot. Moisture percentage was determined at regular intervals in both these soils which were cropped with cotton.

Surface and sub-soil were mostly identical in both the cases. Samples were collected up to depth of 3 ft. in layers of one feet each. Some of the typical results are given in Table IV.

TABLE IV

Movement of water in salt-free lands and saline soils

Nature of soil	Texture	Moisture percentage				Total loss	Salt percentage
		Initial After 5 days	After 10 days	After 20 days	After 25 days		
				0—1 ft. layer			
Sweet soil loam	4·5	24·0	14·5	10·8	12·5	11·5	·05—10
Saline soil loam	8·0	23·4	18·9	16·4	18·9	4·5	1·10
				1—2 ft. layer			
Sweet soil sandy loam	1·7	18·9	14·5	11·9	9·8	9·1	·05-0·10
Saline soil loam	7·8	25·1	21·8	21·8	21·2	3·9	1·30
				2—3 ft. layer			
Sweet soil loam	3·1	19·4	15·2	13·8	16·6	2·8	·05-10
Saline sandy loam	13·6	25·2	25·2	22·8	25·7	*Nil*	1·20

Pot culture experiments

Sodium chloride at 0·1, 0·2 and 0·3 per cent of the soil was mixed with sweet soil in soil free of salts. This soil was filled in empty kerosene tins and the moisture was brought to 25 per cent by the addition of water.

A similar set of tins was prepared but with sodium sulphate at 0·6 per cent of the soil and all the tins were then weighed periodically and the amount of water lost recorded. After a time the moisture in all the tins was again brought up to 25 per cent and the periodical determination of losses was repeated. Table V shows the results.

TABLE V

The loss of water in sweet and saline soils

Treatment	Moisture percentage								Total loss
	15/8	21/8	22/8	Total loss	23/8	25/8	27/8	29/8	
Control (Sweet soil)	25·0	15·0	14·0	11·0	25·0	19·0	15·0	13·0	12·0
Sodium chloride—									
0·1 per cent	25·0	15·0	15·0	10·0	25·0	20·0	13·5	14·0	11·0
0·2 per cent	25·0	19·0	17·0	8·0	25·0	22·0	18·0	17·0	8·0
0·3 per cent	25·0	20·0	17·5	7·5	25·0	22·5	20·5	17·5	7·5
Sodium sulphate—									
0·6 per cent	25·0	23·0	20·5	4·5	25·0	23·5	22·0	20·0	5·0

It will be seen from the figures in Table IV that there is more loss of water from sweet soil than saline soil and that the effect is more marked in the first two feet of the soil.

Results of pot culture studies given in Table V have borne out the same conclusion. Results in Table IV prove further that the loss of water varies inversely to the concentration of the salt.

It will be seen from the figures in Tables IV and V that in a given time sweet soil is left poorer in moisture than saline soils. Though there is more moisture in saline soils yet plants can not make use of it as it is not free to be lost. It can therefore be concluded that in identical conditions, more frequent water would be necessary in saline soils than in sweet soil to give identical normal crops.

Summary

The more is the application of water on the surface more is the downward movement of water in the soil.

During the first 35 days of the growth of cotton water is lost mostly by evaporation.

The evaporation is in direct proportion to the amount of water applied on the surface.

The water that is lost during the growing period of cotton by transpiration is in direct proportion to the amount of water applied.

Whatever be the amount of irrigation, the soil is left poorer in the moisture than the original state at the harvest time.

The presence of salts affect the loss of water from the soil due to evaporation and transpiration.

The loss of water is inversely proportional to the amount of salt.

Under identical conditions it is necessary to give more frequent irrigations to saline soils than to sweet soils to get identical normal crop.

The above work was conducted at Agricultural Research Station, Sakrand, under the guidance of the Agricultural Chemist and Soil Physicist, Agricultural Research Station Sakrand.

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Author is thankful to Mr W. J. Jenkins, I.A.S., the then Chief Agricultural Officer in Sind and Rao Bahadur V. A. Tamhane, I.A.S., Agricultural Chemist and Soil Physicist, Sakrand, for their guidance. The author is grateful to Rai Bahadur R. L. Sethi, I.A.S., the present Director of Agriculture, for valuable criticism. Author is also thankful to Mr M. A. Sharma Iyengar, the then Senior Assistant for his valuable advice.

STUDY OF MOVEMENT OF WATER AND SALTS IN SOILS AT THE AGRICULTURAL RESEARCH STATION, SAKRAND—II

By JETHANAND J. CHANDANI, M.Sc. (AGRI.)

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IN Part I of this paper movement of moisture has been described. This part deals with the movement of salts.

It is a fact that one can hardly find an acre of land in Sind free from kalar patch. Beside these patches of kalar one comes across vast stretches of kalar lands in Sind. It was thought necessary to study the movement of salts that constitute kalar in soils. Kalar lands of Sind contain mostly salts of sodium chloride and sodium sulphate and sometimes chlorides of calcium and magnesium. Special feature of kalar soils of Sind is the absence of sodium carbonate and presence of calcium sulphate.

The typical composition of kalar is given below:

Place	Total soluble salts	Ca percentage	SO_4 percentage	Cl percentage
Left bank of Indus	3·40	0·31	1·4	0·81
Right bank of Indus	5·50	0·54	1·68	2·2

When water is applied to the soil the soluble salts, which are present in the soil, are dissolved and they move in all directions with water. They move downwards when there is a large quantity of water which percolates down. They come up to the surface by capillarity when the water is lost either by evaporation or transpiration. They also move horizontally and convert good lands into bad lands. It was therefore thought necessary to study the movement of salts in detail, as the knowledge of the movement of salts would be a great help in reclamation of saline soils.

Study of movement of salts for the purpose of investigation was resolved into the following items:

(1) Vertical movement of salts,

(2) Rise of salts by capillarity, and

(3) Lateral movement of salts.

VERTICAL MOVEMENT OF SALTS

In series of plots different quantities of water were applied at the surface to see the effect of different doses of water on the downward movement of salts.

Soil samples were collected before and after the application of water up to a depth of 4 ft. in layers of 1 ft. each. Samples were collected from five spots to make a composite sample.

The nature of surface and sub-soil was nearly identical. The physical texture of the area under investigation was as under:

Layer	Sand	Salt	Clay
0—1 ft.	26·0 per cent.	42·0 per cent.	17·0 per cent.
1—2 ft.	24·0 ,,	48·0 ,,	17·0 ,,

M

The quantities of water and the system in which water was applied are shown in Table I.

TABLE I

The quantity of water and how it was applied

	Quantity of water in in.	How applied
A	6·0	All in one dose
B	8·0	All in one dose
C	12·0	6·0 in. once 6·0 in. afterwards on the third day
D	24·0	8·0 in. every week
E	32·0	8·0 in. every week

Some of the typical results are given in Table II.

TABLE II

The vertical downward movement of salt as a result of irrigation

Layer in ft.	Percentage of total Soluble salts		Quantity of water applied in in.
	Before application of water	5 days after application of water	
0—1	2·0	1·8	6·0
0—1	2·1	1·8	8·0
0—1	1·3	1·2	12·0
0—1	1·7	1·0	24·0
0—1	1·3	0·5	32·0
1—2	1·0	1·3	6·0
1—2	1·1	0·8	8·0
1—2	1·3	0·8	12·0
1—2	0·9	0·7	24·0
1—2	1·1	0·7	32·0
2—3	0·2	0·5	6·0
2—3	1·2	0·7	8·0
2—3	0·5	0·46	12·0
2—3	0·6	0·6	24·0
2—3	1·2	0·8	32·0
3—4	0·5	0·5	6·0
3—4	0·9	0·6	8·0
3—4	0·96	0·3	12·0
3—4	0·7	0·7	24·0
3—4	0·6	0·6	32·0

Figures in Table II indicate that the greater is the amount of water applied at the surface, the greater is the vertical downwards movement of salts. This indicates that in saline soils higher initial doses are beneficial to leach out salts from the surface and make the surface fit enough to carry normal crops.

Samples of moisture were taken up to a depth of 11 ft. in plots getting higher initial doses and it was observed there was no accumulation of water in the substrata. Readings of sub-soil water level in some of these plots showed that the sub-soil water level was not affected by the application of as high a dose as 32·0 in.

It was further observed that the movement of the chief sodium salts found in soil, viz. sodium chloride and sodium sulphate, is not the same with the same quantity of water. Results given in Table III below show the relative movement of sodium salts.

TABLE III

The relative amounts of sodium salts

Layer in ft.	Percentage of salts					
	Original		After leaching of 32·0 in. of water		After cotton harvest (8 months)	
	NaCl	Na_2SO_4	Na Cl	Na_2SO_4	Na Cl	Na_2SO_4
1	2	3	4	5	6	7
0—1 . .	0·6	1·1	0·06	0·8	0·22	0·6
0—1 . .	0·3	0·6	0·015	0·2	0·08	0·3
0—1 . .	0·26	0·86	0·030	0·65	0·13	0·5
0—1 . .	0·15	0·50	0·045	0·30	0·24	0·5

Figures given in Table III show that the sodium chloride is leached out prior to sodium sulphate, and even in upward direction it is sodium chloride which comes up quicker than sodium sulphate. This phenomenon has been studied by many workers all over the world.

King [1904] says that the sodium sulphate is absorbed by the soil while sodium chloride is not. Headden [1903, 1918] also is of like opinion. According to Warrington [1900] soil has a slight retentive power for the acid radical of sulphate but none for nitrates, chlorides and carbonates.

Crowther and Basu [1931] found that nonovalent radicals rise by capillarity to the surface faster than divalent radicals. The phenomenon observed here agrees with the findings of research workers in the various parts of the world.

UPWARD MOVEMENTS OF SALTS

It is a common observation that the salts do come up to the surface by capillarity. In the present case such movement of salts within first 6 ft. was studdied at regular interval of 30 days in plots cropped with cotton and plots left fallow. Both these plots got the same amount of irrigation at the same time. Some of the typical results are given in Table IV.

TABLE IV

Upward movement of salts

Layer in in.	Percentge of total soluble salts				
	Initial	After 30 days	After 60 days	After 90 days	After 120 days
			Cropped plots		
0—6	1·1	1·3	1·1	1·3	1·1
6—12	1·1	0·8	1·0	0·7	0·6
12—24	1·0	0·7	0·8	0·6	0·7
24—42	0·7	0·6	0·6	0·6	0·6
42—60	0·6	0·6	0·9	0·5	0·5
60—72	0·7	0·7	0·8	0·7	0·7
			Fallow plots		
0—6	1·0	2·0	1·9	1·6	1·8
6—12	1·8	2·0	1·5	1·7	1·6
12—24	0·8	1·7	1·2	1·5	1·1
24—42	0·9	0·9	0·7	1·0	0·8
42—60	1·0	1·4	0·9	0·6	0·8
60—72	1·4	1·5	1·20	1·2	1·3

There is a well-known proverb in Sind that fallow makes sweet land better and kalar lands worse. This is borne out from figures given in Table IV.

Since the process of accumulation of salts is reduced by cropping, it will be an advantageous and economical proposition if kalar lands, once brought under cultivation, are cropped continuously for some years till the salt content is reduced to such an extent as to permit plant growth.

Lateral movement of salts

It is a common observation in Sind that strips of land stretching from either sides of the canals and water courses become infested with salts in course of time and that lands when brought under irrigation develop kalar and become infertile. These phenomenon are obviously due to certain movements of salts in soil under the influence and help of irrigation water.

It is known that salts freely move upwards and downwards with the movement of water but the extent to which salts move laterally is not definitely known. Experiments were conducted at the Agricultural Research Station, Sakrand, to study if the salts move laterally and if so to determine the rates of migration.

The procedure

A pit $1\frac{1}{2}$ ft. $\times 1\frac{1}{2}$ ft. $\times 1\frac{1}{2}$ ft. was dug in sweet soil of sandy loam texture and the bottom of the pit was cemented so as not to allow any water to percolate down from the bottom of the pit. Two trenches, A and B, 10 ft. long and $1\frac{1}{2}$ ft. deep, were dug on the east and the south of the pit and at right angles to each other. The bottom of the trenches was then cemented and again filled with soil and rammed. The other two sides of the pit were left in natural condition. The pit was then filled with 0·5 per cent solution of commercial potassium chromate. After preliminary trials this salt was selected for the experiment for the following reasons :

(1) Its absence in the soil
(2) Its high solubility
(3) Its low absorption by the soil
(4) Its easy detection in the soil extract by qualitative analysis, and
(5) Its yellow colour which helps to identify it as it travels further from the source.

Potassium permanganate was also tried but it was considerably absorbed by the soil, it was affected by the organic matter in the soil and its qualitative determination was not so easy.

Constant level of solution was maintained in the pit by addition of fresh solution whenever required. At the intervals of a month, samples of soil up to 18 in. depth were taken along the cemented and undisturbed sides, at distances of one foot from the edge of the pit, and each of the samples was tested for potassium chromate. From the distances travelled and time taken to travel those distances, the rate and extent of lateral migration of the salt in the soil were arrived at.

TABLE V

Lateral migration of potassium chromate

No. of days after start	Date of Sampling	Total distances in ft. travelled in different sides from the edge of the pit				Remarks
		A	B	C	D	
15	17-3-31	2	3	2	2	
46	17-4-31	3	3	3	4	
73	14-5-31	3	3	5	5	Rain fall 0·01 in.
121	1-7-31	4	4	5	5	,, 1·89 ,,
148	29-7-31	6	6	6	5	,, 0·90 ,,
179	28-8-31	6	6	6	6	

It would be seen from the results given in Table V that salts move laterally and that the lateral movement is greatest in the first two weeks. It then goes on decreasing till the 73rd day after which the movement of salts is very little. In sandy loam the average movement of salts is 1 foot per month provided that there is a constant head of water. It is also observed that after period of six months the lateral movement of salts is rather little. While attempting reclamation by heavy doses of water good lands should be separated from kalar lands by means of drain or any other device so that salts do not move laterally from kalar lands to good land.

Summary

The more water is applied on the surface, the more washing down of salts from the surface layer is effected. Application of 32·0 in. on the surface depletes the surface soils of soluble salts and makes it fit for general cultivation. Of the injurious salts, the more injurious sodium chloride is washed down more quickly than the less injurious sodium sulphate. Salts once washed down come up to the surface, the more injurious sodium chloride comes up more quickly than the less injurious sodium sulphate, but cropping retards the rise of salts. Saline soils should therefore be kept under continuous cropping during the process of reclamation.

It is proved that the salts move laterally and the method of studying the lateral movement of salts is described.

The above work was conducted at the Agricultural Research Station, Sakrand, between 1930-1935 under the guidance of the Agricultural Chemist and Soil Physicist, Agricultural Research Station, Sakrand.

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CANNING TRIALS ON FRUITS

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Out of the factors responsible for the success of the fruit canning industry, production of a canned product of uniform high quality is very important. This can be achieved by canning sound and fully ripe fruit of varieties best suited for the purpose. Since it is known that all varieties of a fruit are not suitable for canning, resort has to be made for conducting small scale canning trials for the selection of varieties suitable for canning. Such trials are of vital importance for a successful venture in the canning line in our country, where literature regarding the suitability of different varieties of fruits for canning is scanty.

A good canning variety of any fruit must have suitably firm texture and fully developed characteristic aroma of the fruit, so that minimum change is effected in the real characteristics of the original fruit during the process of canning. Selection of varieties like early, late, etc. is also important from the point of view of spreading the canning season over as long a period as possible.

Among the fruits canned in California [Cruess, 1938], peaches, apricots and pears are most common, and a good deal of work has been done there in the way of selection of suitable canning varieties of these fruits. In India although a fairly large number of varieties (both local and imported) of various fruits are at present grown in different parts of the country, no systematic work has so far been carried out for determining their canning quality, except at Quetta [Siddappa, 1942], on the canning of apricots grown in Baluchistan, and at Lyallpur [Lal Singh and Girdhari Lal, 1944], on canning of pears, grown in Kulu (Punjab). It is hoped that the present article which deals with the canning trials carried out in the Fruit Products Laboratories, Lyallpur, on the important commercial varieties of plum, peach, apricot and pear grown in the United Provinces [Saharanpur and Chaubattia (Kumaon Hill) Circles], Kashmir and Punjab (Palampur), will contribute to this end. This investigation was started in 1941, at the instance of the Supply Department (Government of India), with a view to select good canning varieties of these fruits, grown in different localities.

Material

Fruit. The fruit used for canning should be fully ripe and must have developed, as much as possible, the characteristic tree ripe flavour ; but it should not be too soft and over-ripe, as such fruit does not stand preparation and processing during canning. In most cases fruit is picked at firm 'ripe' stage, when the colour has fully developed but before it acquires softness associated with the ripe dessert stage [Hirst and Adams, 1936], and, as far as possible, it is canned the same day. This requires the fruit to be quickly transported from the farm to the cannery.

In the present investigation great difficulty was experienced in getting the fruit of uniform stage of ripeness. As the fruit had to be transported over fairly long distances ; some of the consignments arrived in an unsatisfactory condition, i.e. the fruit was not uniformly ripe. Out of each consignment a fair proportion of fruit had to be rejected while selecting the right type of fruit for canning. It was due to the facilities of cold storage available in these laboratories that the canning trials were possible. Hard but fully developed fruits were allowed in each case to ripen in cold storage (temperature 60-70°F.) until these became fit for canning. Due care was also taken in the final selection of fruits used in canning.

Fourteen different varieties of plum, ten of peach, five of apricot and three of pear were used in these trials. Names of these varieties along with the source of their origin are given in Table I.

General characteristics like colour, size, number of fruits per pound, etc. of the different varieties, which have been tested, are given in Table II, which is self-explanatory. Peaches were mostly freestone type, most of the varieties being white fleshed. Plum varieties were red, purple, golden and greenish, and of varying sizes. Apricots were yellow except one white variety, obtained locally

(produce of Quetta). In California, Williams' is the most common out of pears, and yellow varieties of apricots are preferred to white ones. Plums used are of red varieties, but there is good demand for golden ones also. Peaches are generally yellow-coloured clingstone varieties, but recently interest has been shown in the canning of freestone varieties also [Mottern and Neubert, 1940; and Caldwell and Culpepper, 1944].

TABLE I

Varieties of plum, peach, apricot and pear used in canning trials

Serial No.	Fruit Varieties				Locality
	Plums	Peaches	Apricots	Pears	
1	Alfa	(1) Bidwill's Early (Clingstone).	..	1. Leconte	Saharanpur (United Provinces)
2	Alubukhara (plum) large	(2) Country (freestone)	..	..	Do.
3	Ladak	....	..	..	Do.
4	Howe	....	..	..	Do.
5	Excelsior	....	..	..	Do.
6	French Red	....	..	..	Do.
7	Kelsey's Japan	....	..	..	Do.
8	Satsuma	(3) "Quetta"	1. Large	2. Williams'	Kashmir
9	Yellow Prune	....	2. Small	3. X'mas	Do.
10	Victoria	....	..	..	Do.
11	Chabot	....	..	..	Palampur (Punjab)
12	Satsuma	....	..	..	Do.
13	Merriposa	....	..	..	Do.
14	Jefferson	(4) Foster	3. Large early	..	Chaubattia (United Provinces)
15	....	(5) Red Nectarine	4. Turkey	..	Do.
16	....	(6) Alton (freestone)	..	..	Do.
17	....	(7) Carmon (freestone)	..	..	Do.
18	....	(8) Fitzgerald (frees tone)	..	..	Do.
19	....	(9) English gland (freestone)	..	..	Do.
20	....	(10) Princess of Wales (frees tone)	..	..	Do.
21	....	....	5. Charmagaz	..	Quetta (Baluchistan)

TABLE II

Characteristics of the fresh fruits

Serial No.	Name of variety	No. of fruits per lb.	Physical characteristics
		1. *Plums*	
1	Alfa	45—47	Small sized red plum
2	Ladak	34—37	Small sized, texture rather hard; colour greenish yellow with reddish tinge
3	Howe	30	Medium sized, rather hard, unripe and sour; colour reddish yellow
4	Alubukhara (plum) Large	34—37	Small sized plum of straw yellow colour
5	Excelsior	31—37	Small sized, rather hard and unripe; colour greenish red
6	French red	32—54 (average 43)	Small sized, lacking sweetness; reddish colour
7	Kelsey's Japan	13—18 (average 15)	Fairly big size, very hard and perfectly raw; green colour. Did not mature completely and properly even in two weeks in cold storage, but acquired only slight yellowishness and softness
8	Satsuma (Kashmir)	18—19	Fair size, rather hard; colour greenish to purplish crimson. Ripened to crimson colour in cold storage

Serial No.	Name of variety	No. of fruits per lb.	Physical characteristics
9	Yellow Prune	22—23	Fair size, rather hard, under ripe and sour; colour deep brownish. Ripened and softened well in cold storage and developed good taste
10	Victoria	9—10	Big size, skin tough; colour of skin dark purple, flesh yellowish; taste astringent and sour. Flavour did not develop even after one week in cold storage
11	Chabot	14—15 (average 15)	Fairly big size, good texture; golden yellow colour with red flush on surface. Matured very well in cold storage
12	Merriposa	..	Big size, texture good; skin rather dull reddish but flesh of deep red colour, good quality
13	Satsuma (Palampur)	13—17 (average 15)	Fairly big size, texture good; red colour, and good general quality
14	Jefferson	13—17 (average 15)	Fairly big size, unripe; ripened to yellowish colour in cold storage
			2. *Peaches*
1	Bidwill's Early	..	Average sized, white clingstone variety
2	Country	..	Average sized, freestone, pinkish green colour
3	Foster	6—8	Average sized, freestone, texture not firm, golden yellow colour
4	Red Nectarine	6—7	Average sized, freestone, pale yellowish green colour
5	Alton	About 7	Average sized, freestone, rather greenish colour
6	Carmon	6—7	Average sized, freestone; yellowish colour with red flush, flesh pinkish. Deep depression at stalk end
7	Fitzgerald	6—7	Average sized, freestone; golden yellow colour with red flush and mealy bloom on surface, flesh pale yellow and slightly sour
8	Englishgland	9—10	Small sized, freestone, rather unripe and hard; pale yellow colour with tinge of green and red flush
9	Princess of Wales	4—6	Fairly big sized, freestone; pale yellowish green colour with pink flush. Stone cavity deep and of pink colour. Skin thick and tough, flesh pale white and rather sour
10	Quetta	6—7	Medium sized, freestone; yellow colour with red flush. Skin thin, free and tender; flesh tender, very good and of golden yellow colour
			3. *Apricots*
1	Large Early	About 20	Average sized, freestone; golden yellow colour
2	Turkey	About 20	Average sized, freestone; straw coloured
3	Charmagaz	18—20	Average sized, freestone; light pale yellow colour
4	Large	About 9	Big sized, freestone; golden yellow colour, fully ripe and rather soft
5	Small	25—26	Small sized, clingstone; golden yellow colour, fully ripe
			4. *Pears*
1	Leconte	4—5	Fairly good size, greenish colour; not quite soft and fully ripe; lacking in sweetness and flavour; core very hard and stiff
2	Williams'	3—4	Normal size, bright yellow colour after ripening in cold storage and crimson flush on some fruits. Flesh sweet, creamy and juicy, texture firm and flavour good
3	X-mas	2—3	Big sized, yellow colour with light pink flush on some fruits. Flesh rather crisp and dry and not creamy and juicy, lacking in flavour; texture grainy and fibrous

Cans. Fruit-lacquered and plain tin cans with sanitary double seams, are used in canning. Lacquered ones are at present common for canning highly coloured fruits, since even traces of metal dissolved from the plain can wall by the action of the acid on the tin plate, will spoil the colour and appearance of the pack. Pears, apricots and peaches are little affected but blackberries, straw berries, etc. are easily spoilt [Osman and Jones, 1941]. Both lacquered and plain tin cans were,

therefore, used for plums, peaches and apricots, in these tests to find out the difference in the behaviour of these. Pears, however, were canned only in plain cans since lacquered ones are known to suffer badly from pin holing due to the formation of hydrogen swells. The cans before use were washed thoroughly with hot water to remove zinc chloride and destroy bacteria [Anon, 1937].

Sugar. Ordinary white crystalline sugar as available in the market was used for preparing canning syrup required for experiments under this investigation.

METHODS

Methods used in other countries for the commercial canning of plums, peaches, apricots and pears are highly standardized and have been described by Cruess [1938] and Campbell [1937]. The same methods with slight modifications were, in general, followed throughout the investigation. All the varieties of the same fruit were canned under similar conditions. Colour and general appearance of the fruit and the beginning of softness were used as indices of maturity. Grading was done by hand. Syrup used for the canning of each of the fruits was of the same concentration as used in the 'fancy' grades commercially packed in California and eleswhere [Cruess, 1938].

Plums. These were canned 'whole', as usual, after washing them thoroughly with water, in 40° Brix syrup. Skin of the plums invariably bursts during canning [Anon, 1935]. This defect is claimed to be prevented by pricking the fruit with needles prior to canning [Campbell, 1937]. This treatment was tried with some varieties but results were not very satisfactory as the skin even after pricking did show signs of cracking on subsequent examination of the canned product.

Peaches. The fruits were halved by cutting round the suture line. Pits were removed with special pitting spoons and halves placed in a wire gauze basket, were peeled by subjecting them to the action of a boiling 1-2 per cent lye solution for 25 to 40 seconds, in order to cauterize the skin. These were then washed thoroughly in running cold water to remove the peels and excess of lye. After rinsing in 0·35 per cent HCl solution, they were again washed, drained and immediately canned in 55° Brix sugar syrup.

Apricots. The fruits after washing were split into halves like peaches and canned in 55° Brix sugar syrup.

Pears. The fruits were peeled by hand with a special guarded curved knife. The halves until canned were kept in 1·25 per cent common salt solution, to prevent browning. These were washed and canned in 40° Brix sugar syrup.

Processing.—The cans as described under the heading 'Material' were filled with the fruit according to the usual standards. Hot sugar syrup (Table III) was then added and the cans exhausted in stationary kettles for small lots and in a continuous exhauster for bigger lots [Lal Singh and Girdhari Lal, 1941]. These were then sealed immediately with a double seamer and sterilized in stationary cooking tanks, after which they were cooled to avoid overcooking [Anon, 1937]. Pears were cooled thorughly in iced water to prevent their turning pink in the can. The exhausting and processing times required in each case are given in Table III.

TABLE III

The density of canning syrup, and exhaust and processing times in canned fruits

Fruit	Size of can	Density of syrup (Brix°)	Exhaust in (minutes) and temperature	Processing times in minutes at 212°F.	Remarks
Plums	A 2	40	6 at 200°F	10—12	Cooled in water to 100°F. and then stacked
	A 2½	40	8 at 200°F.	15—18	
Peaches	A 2	55	6 at 180—190°F.	20	Water cooled to room temperature and then stacked
	A 2½	55	10 at 180—190°F.	25	
Pears	A 2	40	6 at 180—190°F.	25	Chilled in iced water and then stacked
	A 2½	40	8 at 180—190°F.	30	
Apricots	A 2	55	6 at 180—190°F.	15	Allowed to cool gradually in air
	A 2½	55	8 at 180—190°F.	25	

Cut out Examination

The canned products were examined periodically during a total storate period of over two years, according to the standard cut-out technique of Hirst and Adams [1932]. This consisted of determining the vacuum, gross weight, weight of contents and density of syrup, noting the condition of can, appearance of fruit and syrup, and testing the quantity of the product regarding colour, texture, preparation, taste and flavour, etc. The fruit for this purpose was examined by spreading it on a 15 mesh sieve made of wire of about 0·016 in. diameter, and draining for five minutes. Results of a typical cut-out test of some of the varieties are presented in Table IV.

Table IV

Results of Cut-out tests of important varieties of plum, peach, apricot and pear, carried out during storage

Serial No.	Name and variety of fruit	Date of canning	Date of inspection	Description of can	Gross wt. (gm.)	Vacuum in inches of Hg.	Internal condition of can	Total contents (gm.)	Drained wt. of fruit (gm.)	Cut-out strength of syrup (degrees Brix at 68°F.)
	Plums									
1	*Alubukhara* (plum) Large	11-6-41	1-4-42	A2P	703·5	7·5	Heavy feathering of tin plate	595·7	261·2	23·62
				A2L	641·0	..	Lacquer somewhat corroded	541·0	254·5	23·62
2	Ladak	14-6-41	1-4-42	A2P	719·5	4·5	Heavy feathering of tin plate	617·8	288·6	27·64
				A2L	714·0	2·0	Slight corrosion of lacquer	606·3	295·3	28·64
3	Howe	16-6-41	1-4-42	A2½P	1033·0	8·0	Heavy feathering of tin plate	998·8	425·3	23·63
				A2L	693·8	6·0	Lacquer not affected	592·8	294·0	23·62
4	Kelsey's Japan	30-6-41	1-4-42	A2½P	1018·0	16·5	Heavy feathering and slight blackening of tin plate	883·0	510·0	27·64
				A2L	683·0	19·30	Lacquer intact	574·0	273·5	25·63
5	Satsuma (Kashmir)	9-8-41	2-4-42	A2P	705·2	8·5	Heavy feathering and slight blackening	596·2	313·5	26·99
				A2L	676·0	5·5	Lacquer fairly corroded	570·0	295·0	27·99
6	Yellow Prune	9-8-41	2-4-42	A2½P	1037·0	10·0	Feathering of tin plate	897·0	379·0	32·50
				A2½L	1030·0	12·0	Lacquer intact	886·0	363·0	31·50
7	Chabot	3-7-43	10-5-44	A2L	660·0	7·0	Slight corrosion of lacquer	555·0	295·0	27·21
8	Satsuma (Palampur)	7-7-43	10-5-44	A2P	683·0	10·0	Fair amount of feathering of tin plate, colour changed to steel grey	579·0	311·0	27·24
				A2L	698·0	13·0	Fair corrosion of lacquer, otherwise shining	593·0	312	27·22

TABLE IV—*contd.*

Results of Cut-out tests of important varieties of plum, peach, apricot and pear, carried out during storage—contd.

Serial No.	Name and variety of fruit	Date of canning	Date of inspection	Description of can	Gross wt. (gm.)	Vacuum in inches of Hg.	Internal condition of can	Total contents (gm.)	Drained wt. of fruit (gm.)	Cut-out strength of syrup (degrees Brix at 68°F.)
9	Merriposa . .	29-6-43	10-5-44	A2P	688·0	9·0	Fair feathering, dark steel grey colour of tin plate	583·0	279·0	27·20
				A2L	703·0	15·0	Slight corrosion of lacquer	597·0	204·0	27·26
	Peaches									
10	Fitzgerald . .	14-7-41	5-10-42	A2½P	1040·0	10·0	Fair feathering and blackening of tin plate	907·0	492·5	32·12
				A2L	718·0	8·0	Lacquer fairly corroded	609·5	337·5	30·60
11	'Quetta' .	23-8-41	5-10-42	A2P	725·0	12·0	Fair feathering and blackening of tin plate	615·0	379·5	29·58
				A2½L	1046·5	9·0	Lacquer corroded to a fair degree	916·5	496·0	29·58
	Apricots									
12	Charmagaz .	7-6-41	24-1-42	A2½L	1068·0	11·5	Slight corrosion of the lacquer	924·5	407·5	35·82
				A2P	721·0	12·5	Feathering of tin plate	616·0	273·0	32·82
	Pears									
13	Williams . .	22-8-41	4-4-42	A2P	702·0	11·0	Feathering of tin plate	597·0	325·0	29·56

L=Lacquered cans
P=Plain cans

No. of fruits or pieces	APPEARANCE		Firmness	General quality, taste and flavour	REMARKS
	Fruit	Syrup			
30	Skin burst, golden yellow colour, attractive appearance	Fairly clear	Fairly firm .	Skin rather hard, taste and flavour fairly good	
31	Ditto . .	Ditto	Ditto .	Ditto	
30	Skin and flesh somewhat burst, attractive golden yellow colour	Ditto	Ditto .	Skin rather hard, flesh fair; taste and flavour very good	
28	Ditto . .	Ditto	Ditto .	Ditto	
35	Rather discoloured (brownish) and not very attractive colour; otherwise good	Ditto	Good . .	Good	
26	Brownish colour, otherwise good	Ditto	Do. . .	Do.	
15	Skin and flesh somewhat burst, attractive greenish yellow colour	Clear	Rather hard .	Flesh and skin very good in eating although slightly hard; rather lacking in sweetness, otherwise taste and flavour good	
12	Ditto . .	Do	Ditto .	Ditto	

TABLE IV—*concld.*

Results of Cut-out tests of important varieties of plum, peach, apricot and pear, carried out during storage—concld.

No. of fruits or pieces	Appearance		Firmness	General quality, taste and flavour	Remarks
	Fruit	Syrup			
10	Skin rather burst, fruit discoloured changing to dull brownish violet	Dull violetish unattractive colour; otherwise fairly clear	Fairly firm .	Excepting slight acidity, taste and flavour good; flesh very good in eating	
10	Skin somewhat cracked, colour better than above	Fairly clear, bright deep red colour	Ditto .	Ditto	
22	Skin, burst, otherwise good; attractive brownish yellow colour, fl sh of bright yellow colour	Dull pinkish colour, otherwise fairly clear	Quite firm .	Skin slightly hard otherwise good and pleasant in eating; flesh very good. Taste and flavour very good	It can give excellent product if canned after peeling
23	Ditto . .	Attractive, bright deep pinkish colour; clear	Ditto .	Ditto	
13	Skin removed, otherwise appearance good; attractive golden yellow colour	Rather turbid, but colour attractive brownish yellow	Slightly soft .	Eating quality and texture very good, taste and flavour excellent	
11	Good brownish violet colour, attractive appearance	Fairly clear, reddish colour .	Good . .	Texture and flesh of fruit and eating quality very good; taste and flavour very good	
10	Good reddish colour, attractive appearance	Clear; deep red colour .	Do. . .	Ditto	
7	Rather dull brownish colour, otherwise very good in appearance	Rather dull light pinkish colour; fairly clear	Fairly good .	Ditto	
7	Good attractive bright brownish colour and very good appearance	Red coloured clear syrup .	Ditto .	Ditto	
10	Very good and attractive appearace, golden yellow colour	Clear of light pale yellow colour	Slightly hard .	Except for slight hardness, flesh and eating quality very good. Taste and flavour very good	
8	Ditto . .	Ditto . .	Ditto .	Ditto	
16 pieces	Very good attractive appearance; soft ripe fruit of deep orange yellow colour	Except for slight suspended fruit particles, syrup clear	Fairly good .	Flesh and eating quality very good; taste and flavour very good	
30 pieces	Ditto . .	Ditto . .	Ditto .	Ditto	
43 halves	Condition of fruit very good; halves of bright attractive colour and appearance	Fairly clear, light yellow colour	Good . .	Skin and fibre somewhat hard, good and pleasant in eating. Taste and flavour very good and natural	
30 halves	Ditto . .	Ditto . .	Do. . .	Ditto	
7 halves	Very slight violet tinge in colour, appearance very good and attractive	Fairly clear	Do. . .	Texture very good and soft, pleasant eating quality; flavour and taste very good	

DISCUSSION OF RESULTS

As a result of the above cut-out examinations, the best canning varieties of the different fruits, viz. plums, peaches, apricots and pears, as reported in this article along with their places of origin, are given in Table V.

Plum. As seen from Table V, varieties of plum like Alubukhara (plum) Large, Ladak, Howe, Kelsey's Japan (United Provinces); Satsuma, Yellow prune (Kashmir); Chabot, Satsuma, Merriposa (Palampur), were found to be good canners. Out of these, Chabot, Satsuma and Yellow prune varieties gave comparatively the best product. Kelsey's Japan would have given a very good

product, but it did not, since the fruit was rather raw and never attained its full maturity even during storage, therefore remaining hard after canning with low sugar penetration; yet in spite of these it yielded a reasonably good product. For the same reasons 'Victoria' variety did not yield a suitable canned product, although it is known to be a good canner [Hirst and Adams, 1936]. It is therefore presumed that if picked at the right stage of maturity, it would yield a canned product of good quality.

TABLE V

Best Canning varieties of plum, peach, apricot and pear

Fruit	Varieties	Place of origin
1. Plum	1. *Alubukhara* (plum) Large	Saharanpur (United Provinces)
	2. Ladak	Ditto
	3. Howe	Ditto
	4. Kelsey's Japan	Ditto
	5. Satsuma.	Kashmir
	6. Yellow Prune	Ditto
	7. Chabot	Palampur (Punjab)
	8. Satsuma	Ditto
	9. Merriposa	Ditto
2. Peach	1. 'Quetta'	Kashmir
	2. Fitzgerald	Chaubattia (United Provinces)
3. Apricot	1. Charmagaz	Obtained locally (produce of Quetta, Baluchistan)
4. Pear	1. Williams'	Kashmir

Original colour of canned plums in all cases underwent marked adverse changes during storage. In general, colour retention was better in lacquered cans than in plain ones. Lacquered cans on the other hand suffered from a fair degree of corrosion which subsequently caused pinholing and perforations. This was first observed after about 7-9 months' storage and continued to a varying degree in nine varieties out of the fourteen tried. It may be mentioned here that experiments which were exclusively carried out in these laboratories [Anon, 1942-43 and 1943-44] on the formation of hydrogen swells in different fruits, indicated that in a period of about two years' storage, percentage spoilage due to hydrogen swell formation in the case of plums was to the extent of about 18·0 per cent.

Spoilage due to pin-holing and hydrogen swell formation is directly connected with cracks produced in the lacquer coating during can reforming, however carefully it may be done. The latest technique of lacquering cans after fabrication ('post' or 'flush' lacquering), has been claimed by Hirst and Adams [1939] to provide complete protection against hydrogen swells for about three years under normal conditions. In the absence of these 'flush lacquered' cans, it would appear that colour and appearance of plums may have to be sacrificed by using plain cans instead of those lacquered in the ordinary manner, for packing this fruit for storage over more than six months.

Peaches. Two yellow varieties, namely 'Quetta' and Fitzgerald proved to be the best canners. Foster, and Red Nectarine were promising up to about four months' storage but deteriorated during subsequent storage. Plain as well as lacquered cans behaved almost similarly regarding appearance, taste, etc. of peaches. Product in lacquered cans suffered from hydrogen swells which ultimately caused pin-holing. This was observed after one year's storage in only four varieties and to a lesser extent than in plums. In experiments exclusively conducted on hydrogen swell formation [Anon, 1942-43 and 1943-44] spoilage due to this trouble was to the extent of about 4·0 per cent in about two years' storage.

Apricots. Only 'Charmagaz' yielded a product of good quality, others became fairly mashy during canning and had an acidic taste. No difference was noticed in the general quality of the product packed in plain or lacquered cans. Plain cans showed a fairly high degree of feathering and

lacquered ones slight corrosion of lacquer which was more pronounced in the yellow varieties. Pin-holing was observed in three varieties packed in lacquered cans, after about 17 months' storage.

Pears. Only Williams' proved to be a good canner and gave a product of excellent texture, flavour and taste; other varieties lacked in these characteristics. This variety as grown in Kulu valley (Punjab) has also been found to be a good canner by Lal Singh and Girdhari Lal [1941, 1944]. It has also been reported by Hirst and Adams [1936] to be an extensively canned variety of pear in California.

Summary

Trials have been carried out on the canning of fourteen varieties of plum, ten of peach, five of apricot and three of pear, grown in the United Provinces (Chaubattia and Saharanpur circles), Kashmir and the Punjab with a view to select good canning varieties of these fruits. Data on the physical characteristics of fruit of all the varieties such as size, colour, number of fruits per pound, etc., have been given. Behaviour of these in plain as well as lacquered cans during a storage period of about two years has been discussed. Out of all the varieties, Alubukhara (plum) Large, Ladak, Howe, Kelsey's Japan (Saharanpur), Satsuma, Yellow prune (Kashmir), Chabot, Satsuma and Merriposa (Palampur) varieties of plum, 'Quetta' (Kashmir) and Fitzgerald (Chaubattia) varieties of peach, 'Charmagaz' (obtained locally produce of Quetta) variety of apricot and Williams' (Kashmir) variety of pear have been found to be good canners. The results of typical cut-out tests of all these varieties have also been given.

Acknowledgments

The authors wish to express their thanks to Sardar Bahadur Sardar Lal Singh, Fruit Development Adviser to the Government of India (formerly, Fruit Specialist, Punjab) for his valuable suggestions and criticism during the course of this investigation and to the Imperial Council of Agricultural Research for the research grant to the scheme under which this work was carried out.

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PLANT QUARANTINE NOTIFICATIONS

Plant Quarantine Notifications of the Government of India, Department of Agriculture, Bureau of Plant Protection and Quarantines

Notice No. 2 of 1946

Notifications of Foreign Quarantine Restrictions received during July-December, 1946.

The following Plant Quarantine Notifications have been received in the Bureau. Those interested are advised to apply for details to the Plant Protection Adviser to the Government of India.

1. Plant—Quarantine Import Notifications of the Dominion Republic; B. E. P. Q. No. 396—Supplement No. 3, dated 22nd August, 1946, issued by the U. S. Dept. of Agriculture.	Prohibiting importation of tomato and Pepper Seed into the Dominion Republic without certificates of Disinfection with mercury compounds to prevent the introduction of the "Bacterial Spot".
2. Plant—Quarantine Import Notifications of the United Kingdom of Great Britain; B. E. P. Q. No. 416, Supplement No. 2, dated 22nd August, 1946, issued by the U. S. Dept. of Agriculture.	Regarding restrictions of importation of Raw Cherriers into Scotland after 18th May from any country other than Belgium, France or the Netherlands to prevent the introduction of the Cherry Fruit Fly. A similar restriction has been placed by the Ministry of Agriculture and Fisheries in regard to the import of cherries into England walls after the 27th May, 1946 from France, according to the Int. Bull. of Plant Protection, Rome, October, 1946.
3. Plant—Quarantine Import Notification of the Union of South Africa B. E. P. Q. No. 47, Supplement No. 4, dated the 22nd August, 1946, issued by the U. S. Dept. of Agriculture.	Notifying a revision of regulations concerning citrus fruits potatoes, etc.
4. Plant—Quarantine Import Notifications of Newfoundland B. E. P. Q. No. 554, dated 22nd August 1946, issued by the U. S. Department of Agricutlure.	Although Newfoundland has no plant quarantine regulations, certification, is required with all importation of plants and seeds.
5. Plant—Quarantine Import Restrictions of the Union of Soviet Socialist Republics; B. E. P. Q. No. 425—Revised, dated the 26th August, 1946, issued by the U. S. Department of Agriculture.	Contains a summary of the plant-quarantine import restrictions of the U. S. S. R. for the information of importers, etc.
6. Plant—Quarantine Import Restrictions of the Republic of Venezuela, B. E. P. Q. No. 497—Revised, dated the 30th August, 1946, issued by the U. S. Department of Agriculture.	A digest of the plant-quarantine import restriction of the Republic of Venezuela for the information of nurserymen, etc.
7. Plant—Quarantine Import Restrictions of the Republic of Uruguay; B. E. P. Q. No. 382—Supplement No. 1—Revised, dated the 27th September, 1946, issued by the U. S. Department of Agriculture.	Deals with revised restrictions on the importation of seed potatoes into Uruguay.
8. Plant—Quarantine Import Restrictions of the French Zone of Morocco; B. E. P. Q. No. 444, 2nd Revision; dated 4th November, 1946, issued by the U. S. A. Department of Agriculture.	This is a revision of the digest of the plant-quarantine import restrictions of the French Zone of Morocco for the use of nurserymen, plant-quarantine officials and others.

The following notification pertaining to the period January to June 1946 was received too late for inclusion in Notice No. 1 of 1946.

9. Plant—Quarantine Import Restrictions of the Colony of Mozambique; B. E. P. Q. No. 550, dated 23rd April, 1946; issued by the U. S. A. Department of Agriculture.	A summary of the plant quarantine import restrictions of the Colony of Mozambique for the information of exporters, nurserymen, etc.

Notification No. F.7-12/46-PP (Crops), dated the 17th February 1947 of the Government of India in the Department of Agriculture

IT is hereby notified for general information that the following officers are authorised to inspect and grant health certificates in respect of plants or seeds intended for export to the United

Kingdom and other foreign countries, the Governments of which require a certificate of freedom from disease to accompany consignments of plants.

	Officers
Central Government	(i) The Plant Protection Adviser to the Govern ent of India, Department of Agriculture, New Delhi.
	(ii) The Imperial Entomologist, Indian Agricultural Research Institute, New Delhi.
	(iii) The Imperial Mycologist, Indian Agricultural Research Institute, New Delhi.
	Centrally Administered Areas
Baluchistan	(i) Entomologist.
	(ii) Mycologist.
Ajmer-Merwara	(i) Agricultural Officer.
Coorg	Agricultural Officer.
Andamans and Nicobar Island	Agricultural Officer.
	PROVINCES
Bihar	(i) Entomologist, Department of Agriculture, Bihar.
Bombay	(i) The Plant Pathologist to the Government of Bombay, Poona.
	(ii) The Agricultural Entomologist to the Government of Bombay, Poona.
Assam	(i) The Director of Agriculture, Assam.
	(ii) The Director, Tea Experiment Station, Tocklai.
Madras	(i) The Entomologist to the Government of Madras, Coimbatore.
	(ii) The Mycologist to the Government of Madras, Coimbatore.
Bengal	(i) The Entomologist to the Government of Bengal.
	(ii) The Mycologist to the Government of Bengal.
United Provinces	(i) The Plant Pathologist to the Government of the United Provinces, Cawnpore.
	(ii) The Entomologist to the Government of the United Province, Cawnpore.
The North-West Frontier Province	(i) The Director of Agriculture.
Central Provinces and Berar	(i) The Mycologist to the Government of Central Provinces and Berar.
	(ii) The Entomologist to the Government of Central Provinces and Berar.
Sind	(i) Mycologist, Agriculture College, Sakrand.
	(ii) Entomologist, Agriculture College, Sakrand.
Punjab	(i) Mycologist, Punjab Agricultural College, Lyallpur.
	(ii) Entomologist, Punjab Agricultural College, Lyallpur.
Orissa	(i) The Director of Agriculture, Orissa.
	INDIAN STATES
Travancore	(i) Director of Agriculture.
Hyderabad	(i) Entomologist.
	(ii) Plant Pathologist.
Cochin	Director of Agriculture.
Bikaner	Director of Agriculture and Forests.
Mysore	Director of Agriculture.
Bhopal	Director of Agriculture.
Baroda	Commissioner of Agriculture.
Patiala	Director of Agriculture.
Kashmere	Director of Agriculture.

The information regarding the arrangements made and the fee charged for the inspection and certification of plants or seeds intended for export to foreign countries should be obtained by the exporters from the Provincial or State Government concerned direct.

MGIPC—M—III-1-10—16-7-48—600.

ORIGINAL ARTICLES

EFFECT OF IRRIGATION AND GROWING RICE ON SALINE SOILS

I. MANGANESE, NITROGEN AND PHOSPHATE STATUS OF SOIL

By A. G. Asghar and C. L. Dhawan, Irrigation Research Institute, Lahore (India)

(Received for publication on 25 November 1946)

THE Punjab being an agricultural province its prosperity mainly depends upon the crops it can produce. Since the introduction of canal irrigation there has been a considerable change in the soil and the fertility and crop yields have been affected adversely.

One of the main characteristics of the soil of this area is its tendency to develop salinity, due to which the land becomes unsuitable and uneconomical for cultivation. The deteriorated land locally known as *thur* has a white incrustation and becomes loose and fluffy if sodium sulphate is present in excess and broken up at the surface if sodium chloride predominates. Vast area has thus gone out of cultivation which contains sodium salts evenly or unevenly distributed in the soil profile. Although this has mainly appeared in areas with high water-table still fields with low water-table have also been badly affected.

The formation and reclamation of *thur* lands by irrigation and paddy cultivation has been dealt with by Mehta [1940], Taylor [1940] and the usual method of reclamation is summarized below :

The fields are first levelled, wherever necessary, and the irrigation is commenced about the 15th April. The water is allowed to stand 3·0 in. to 4·0 in. deep, for about two and a half months. During this period it has been observed that the conductivity of the water standing over the field falls gradually. The field is then ploughed and the rice seedlings are transplanted. The general *varabandi* system in this province is worked weekly and 3·0 in. of irrigation is usually given on each turn. The total amount of water used for leaching and for growth of one rice crop is about seventy inches. The rice is harvested in the month of October, followed by a predetermined rotation of crops.

It is evident that during the reclamation there would be a number of soil reactions taking place. The fertility of the soil which depends upon various factors is an essential condition which must not deteriorate during reclamation processes. The present paper deals with the effect of reclamation on the nutritive elements, *i.e.*, manganese, nitrogen and phosphorus.

Experimental

(a) Sampling

Soil samples were taken from three different villages on Upper Chenab Canal. The first sampling was done before reclamation. The place from where a sample was taken was marked by noting the perpendicular distances from the two adjoining boundaries of the field. The samples were taken by the help of soil auger which could make a bore of 3 in. and could be pushed into the soil by rotation. Samples representing each foot were collected up to 2 ft. depth from one acre area. After reclamation the sampling was repeated taking care that the spot selected was as near as possible from where the previous sample was collected.

(b) Preparation of samples for analysis

The soil samples were sun-dried, powdered, sieved through 2 mm. sieve and properly labelled.

(c) Analysis

The following is a brief description of the technique adopted for analysis :

1. Manganese was determined by the Bismuthate method [*Bulletin Imperial Bureau of Soil Science*, 1937].

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2. The Phosphates were extracted from soils by Trug method [1930] and Deniges technique as elaborated by Chapman [1932] was used to develop colour. The colorimetric comparison was made by Klett colorimeter against colours developed with standard phosphate solutions.
3. Nitrogen was determined by Kjeldahl's method as modified by Bal [1925]. Nitrate was determined by the usual official method of phenol-di-sulphonic acid.

The results of the average values for all the plots before and after reclamation for the first and second foot are given in Table I.

TABLE I

The average values of manganese, nitrogen, nitrate and phosphate contents of soils before and after reclamation

Serial No.	Soil nutrient	0—1·0 ft. (First foot)		1·0 ft.—2·0 ft. (2nd foot)	
		Before reclamation.	After reclamation.	Before reclamation.	After reclamation.
1	Manganese content in m.e. per 100 gm. of soil	3·3	2·6	3·6	3·2
2	Nitrogen content as nitrogen in milligrams per 100 gm. of soil	34·0	15·9	27·4	15·6
3	Nitrate content as sodium nitrate in milligrams per 100 gm. of soil	5·3	3·5	4·5	1·8
4	Phosphate content as P_2O_5 in p.p.m.	14·3	12·6	15·0	10·9

DISCUSSION

Effect of reclamation on manganese content of soil

The average values of manganese content in m.e. per 100 gram of soil, in the first and second foot before and after reclamation are given in Table I. There is a decrease in manganese content of soil after reclamation which is more in the first foot than in the second.

In the soil, manganese is probably present in the form of dioxide or its hydrate $Mn_20{\cdot}3\ H_2O$. Between pH values of 7 and 9 the manganese dioxide remains insoluble [Britton, 1929]. During the process of leaching under the rice cultivation, carbon dioxide is produced in the root zone of the plants, which not only increases the rate of percolation of water but reduces the pH of the soil. It has been observed by Dastur and Kalyani [1934] that the pH value of the soil in the vicinity of the roots of the plant generally remains below 7. The pH value of the roots of the plant may be still lower. According to the observation of Puri and Uppal [1938] the pH value of a soil is decreased to about 5 in many cases depending upon the nature of soil and below 7 in all cases. The pH of carbon-dioxide solution is about 4 and therefore the pH of the soil in a solution of carbon dioxide is bound to decrease.

The manganese compound being more soluble below pH 7·0, the decrease in the manganese content of the soil after reclamation can be easily explained. The water passing through soil on reaching the root zone dissolves carbon-dioxide in which the manganese compound is soluble and is leached out.

Effect of reclamation on nitrogen content of soil

The average values of nitrogen and nitrate in the first and second foot before and after reclamation are included in Table I. The nitrogen content of the soil as well as nitrate show a considerable decrease after reclamation.

A large amount of work has been done on the absorption of nitrogen by rice plant by various workers. Nitrogen may be present in the form of ammonia or nitrate and the intake depends upon

the age of the plant. Kelley [1911] and Trelease and Paulino [1920] have shown that in the earlier stages the ammoniacal nitrogen is absorbed while, in the latter stages of the growth, the nitrate-nitrogen is preferably taken up. The loss of nitrogen from the soil bearing rice would thus be due to absorption by the plant in the first instance.

At Rothamstead [Russel, 1942] it was observed that a plot kept under irrigation, but without any crop, lost nitrogen. The loss was found to be equal to the nitrogen in the leachate, which was 25 lb. to 40 lb. per acre per annum. In the case of soil under crop the loss of nitrogen was less as the discharge of leachate decreased due to the absorption of moisture by the plants. It is estimated that after making an allowance for the absorption of nitrogen by the plants and its loss due to other agencies, the soil may lose about 70 per cent of the added quantity of nitrogen due to leaching only.

De and Pain [1936] has pointed out that under water-logged conditions or if the soil is kept submerged under water for long periods the aerobic nitrogen fixing organism is totally destroyed. This is the condition in rice cultivation when the soil remains submerged for about two and a half months intermittently.

Effect of reclamation on phosphate content of the soil

The average values of phosphate content in p.p.m. as P_2O_5 before and after reclamation are given in Table I. There is more decrease of phosphate content in the second foot than in the first foot.

Carbon dioxide is known to play an important part in the reclamation of alkali soils [Puri and Puri, 1938; Puri and Uppal, 1938]. Puri and Asghar [1936] worked out the carbon dioxide method of phosphate determination which corresponds to natural conditions in the field. The *p*H value of the solution of carbon dioxide is about 4. The carbon dioxide produced at the roots of the plant, therefore, plays the following role:—

1. It lowers the *p*H value.
2. It deflocculates the dispersed soil and increases the rate of percolation.
3. It dissolves the available phosphates of the soil.
4. It brings more of the exchangeable sodium of the soil into solution.

The availability of phosphorus for rice plants depends upon the amount of soluble phosphorus. It has been observed by Bartholomew [1930] that flooding of soils causes fixation of phosphorus and, as it becomes insoluble, its availability to plant decreases. Further that the rice soils generally do not respond to phosphatic manures. This observation was made in regions where irrigation water contained a high amount of basic material.

The water used for reclamation of plots under discussion was taken from Upper Chenab Canal, the analysis of which is given in Table II. The water does not contain any aluminium or iron oxide. Hence the deficiency caused in the available phosphorus, cannot be attributed to the conversion of soluble phosphorus to insoluble one by heavy basic ions. Thus the depletion in phosphorus can only be explained as a result of the effect of carbon dioxide produced by the roots of rice plants. This conclusion is supported by McGeorge [1933, 1935] who has pointed out that carbon dioxide is an important factor in governing the *p*H and solubility of phosphorus in the soils.

TABLE II

The results of analyses of the Upper Chenab Canal water (at Chichokimalian)

(All values expressed in part per 10^5)

1	Calcium sulphate	*nil*
2	Calcium carbonate	*nil*
3	Calcium bicarbonate (given as calcium carbonate)	10·00
4	Calcium chloride	*nil*
5	Sodium sulphate	11·40
6	Sodium carbonate	*nil*
7	Sodium bicarbonate (given as sodium carbonate)	1·06
8	Sodium chloride	2·92
9	*Total*	25·38
10	Conductivity	275

The Punjab soils are generally light, the clayey portion overlying a sandy stratum, in which the water table is situated. The depth of clayey layer is different at different places. The percolation of water is an easy process through such profiles. The irrigation water passing through the root zone of the rice plant dissolves carbon dioxide and consequently the available phosphorus is decreased. As the success of reclamation process depends on a higher rate of percolation, this would be accompanied with a higher rate of removal of available phosphorus.

SUMMARY

During the process of reclamation the soil loses very important nutrient elements like manganese, nitrogen and phosphorus.

To maintain fertility it would be necessary to manure the soil after rice cultivation with a leguminous crop which would supply requisite amount of these nutrients.

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LEAF MID-RIB STRUCTURE OF SUGARCANE AS CORRELATED WITH RESISTANCE TO THE TOP-BORER (*SCIRPOPHAGA NIVELLA*. F)*

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(With Plates XII to XIV)

AMONG the borers which attack the sugarcane crop in India, the one which causes the greatest damage is the top-borer, *Scirpophaga Nivella* F. This pest is found in all the sugarcane growing parts of India. The loss caused by this borer is considerable, amounting to even 70 per cent of the crop at the time of harvest in bad cases. Canes attacked by this pest get dry and stunted and 'often have a bunchy top owing to the upper side buds developing into branches'. Moreover, many of the young shoots are killed and prevented from growing into millable canes. During the time of harvest, millable canes attacked by this pest show an average loss of 20 per cent in weight. The canes are attacked even from the time the internodes begin to appear.

The adult is a moth which lays eggs in masses covered with hairs on the sugarcane leaf. The larvae hatching out of the eggs bite into the lower surface of the mid-rib of an 'upper almost fully unfurled leaf' a few inches above the base. Then they burrow into the mid-rib down to the base of the leaf where the leaf is in contact with the shoot and then bite their way into the shoot and kill the main shoot. So the plant either completely perishes or develops side shoots and gets stunted in growth.

REVIEW OF LITERATURE

Very little work has been done on the subject relating to the factors conducive to the resistance of a variety to the top-borer.

Hazelhoff [1929, 1932] made a study of the hardness of the growing point or spindle of *P.O.J. 2878* and *E.K. 28*. He found the growing point of *P.O.J. 2878* to be softer than that of *E.K. 28*. He expressed the belief that *E.K. 28* is more resistant to the top-borer (*Scripophaga auriflia zell* var. *intacta* Sn.) than *P.O.J. 2878* because the growing point of *E.K. 28* is harder than that of *P.O.J. 2878* and hence the newly hatched larva has greater difficulty in effecting entry into *E.K. 28*. He found the top-borer damage to be inversely correlated with the moisture supply.

Hard [1932] was of opinion that the resistance of a variety to top-borer depended upon the dry substance and hence hardness of the growing points. According to him, *P.O.J. 2878* is much preferred by the top-borer *Scirpophaga auriflia zell* var. *intacta* Sn. to other varieties grown in the same field, because the growing point of this variety was more delicate and tender than that of others. He felt that the top-borer attack was inversely proportional to the dry substance content of the growing point.

Isaac [1939] after extensive field observations of cane shoots attacked by the top-borer, *Scirpophaga Nivella* F., found that certain varieties of sugarcane are definitely more resistant to the pest than others. He was of opinion that the resistant varieties have strong and hard mid-ribs, whereas those which are attacked possess weak mid-ribs as indicated by drooping leaves. 'If a larva cannot get into the one particular leaf out of the whole bunch of leaves, it perishes, and what is more important is that, if this particular leaf has a strong mid-rib, the larva is unable to pass into the mid-rib within a certain period from the time of hatching and it perishes for want of food and shelter.' When one larva attacks a plant usually no other larva tries to get into the same plant afterwards.

According to Isaac proof was also available from general observations in sugarcane tracts and from experimental cultivation of different varieties that few top-borers attack varieties of sugarcane like *Co. 331*, *Co. 356*, *Co. 421*, etc., with strong mid-ribs. Some varieties with weak mid-ribs like *Co. 213*, *Co. 312*, *Co. 313*, etc., are badly attacked and reduced to 'bunchy leafy grossy clumps'.

* Part of the thesis approved for the degree of Master of Science of the Madras University

This observation of Isaac naturally attracted attention and the present study was undertaken with a view to finding out whether there is any correlation between the resistance of a variety and the hardness of its leaf mid-rib.

General description of mid-rib anatomy

The anatomy of the mid-rib in sugarcane is dealt with here in general, as it will facilitate proper understanding of the whole problem (Plate XII, fig. 1).

The upper and lower epidermis of the mid-rib possess a layer of cuticle which is more prominent on the lower epidermis. The upper epidermis is even whereas the surface of the lower is ridged. Inside the lower epidermis there is a row of vascular bundle arranged parallel to each other. The vascular bundles are of three different sizes, small, medium and big. These bundles occupy positions against the ridges of the epidermis. The bundle sheaths of these vascular bundles extend to the epidermis. Between the vascular bundles, *i.e.*, against the grooves are thin-walled mesophyll cells containing chloroplasts. Stomata are found only in the grooves. In some varieties there are rows of bristles lining the groove and pointing inwards. The size of the individual bundles and the nature of the sheath vary with the varieties.

Inside this outer row of bundles, there is another row of bigger bundles, also arranged parallel to each other. The bundles comprising this row are of one size and bigger than the bundles of the outer row. They are farther apart from one another than the bundles of the outer row.

Immediately below the lower epidermis there are 3-4 layers of sclerenchymatous cells. Thin-walled cells of the ground tissue occupy the space between these layers and the second row of big vascular bundles.

It will be seen from this general anatomy of the mid-rib that the mechanical tissues, viz. the vascular bundles with their bundle sheaths that give rigidity and hardness to the mid-rib are found on the ventral (lower) side, the dorsal (upper) side being softer and consisting of mostly thin-walled cells. It is to be noticed that the larvae of the top-borer make their entry into the mid-rib by boring on the ventral side which is harder than the dorsal. This may be because the eggs are laid on the under surface of the leaf to protect them against natural enemies.

Material and methods

Mid-rib material of resistant and susceptible varieties were obtained from the Imperial Sugarcane Breeding Station, Coimbatore, situated in Tropical India and also from its Sub-Station at Karnal (Punjab) situated in the sub-tropics. They were preserved in formalin-acetic-alcohol. Wherever possible mid-ribs having the bore made by the larva were studied. In other cases, mid-ribs were obtained from the lowest almost unfurled leaf of the leaf spindles, as it was known that the larva bores into the mid-rib in such leaves. The crop was five months old at the time of study, a time at which the attack of the pest is severe. The study was carried out for two seasons.

Studies at the Sugarcane Sub-Station, Karnal (Punjab), to establish correlation between the counts of egg masses of the top-borer on the leaf of a variety and their reaction to the attack of the pest have resulted in negative results. Hence in the present study no attempt has been made for investigations along those lines.

The figures for the percentage of dead hearts given in Table II were obtained from Karnal as also the mid-ribs of the varieties concerned. As stated before, the attack of this pest is severe only in North India. At Karnal only the popular canes are grown and as such the percentage of dead hearts could be obtained only for these varieties. Many of the other varieties for which the lignification figures are given and for which no percentage of dead hearts have been recorded are only grown at the Sugarcane Breeding Station, Coimbatore, where there is very little incidence of this pest. As such the percentage of dead hearts could not be determined for them. But their mid-rib structure was studied in order to facilitate selection of suitable parents for imparting a hard mid-rib to the progeny.

First to study the method of entry of the larva into the mid-rib, cross sections were taken through the centre of a puncture made by the borer. On examination it was found that the larva bites through a portion of the mid-rib containing 7-8 of the vascular bundles of the outer row. The average distance

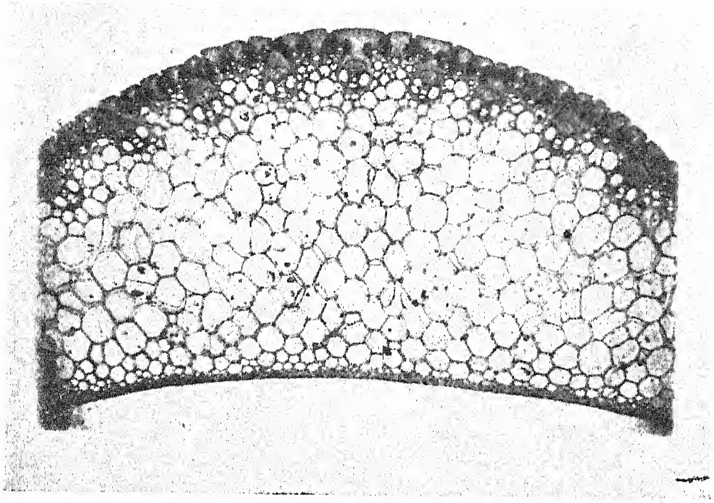


FIG. 1. Transverse section of leaf mid-rib of *Co.* 312 uneffected.

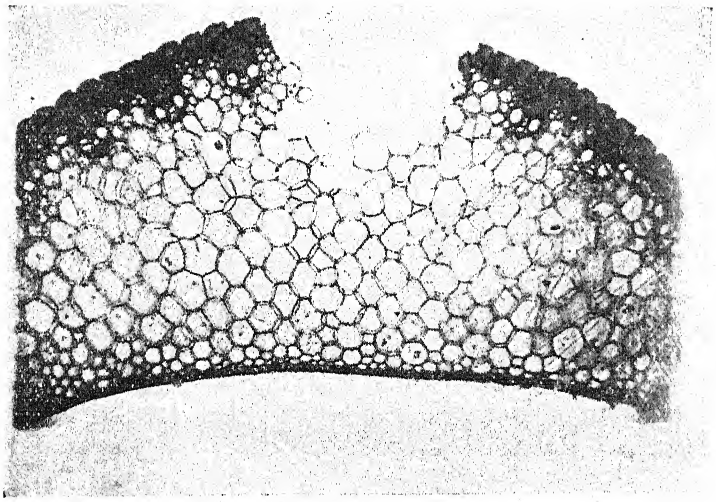
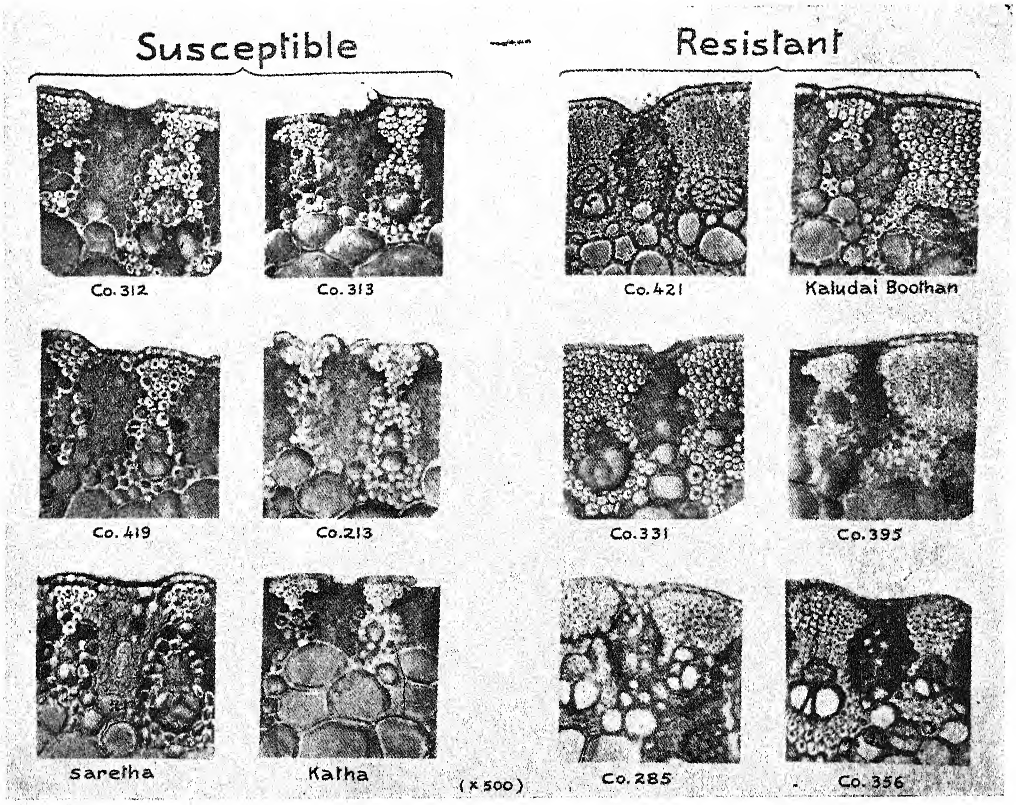


FIG. 2. Transverse section of leaf mid-rib of *Co.* 312 affected and the top borer showing the extent of damage to the vascular tissues.



Cross section of midribs showing the resistant varieties with more ligrified and better developed bundle sheath than those of the susceptible varieties.

which separate the vascular bundles of the outer row even in very susceptible varieties is not more than 0·06 mm. Since the larva is more than half a millimetre in size, it cannot pass into the mid-rib between two neighbouring bundles, *i.e.* through the soft mesophyll tissue. It must bite through a number of bundles to get into the mid-rib. In the photograph (Plate XII, fig. 2) is reproduced a cross section through the centre of a puncture made by the borer. Some indication is given of the number of bundles eaten by such penetration.

The thickness and nature of the bundle sheath should, therefore, play a prominent part in facilitating or checking the entry of the larva. Thus, if the sheath is well developed and its cells are thick-walled, the mid-rib will be rendered hard and the larva will find it difficult to eat its way through. On the other hand if the bundle sheath is not well developed, the mid-rib will be soft and the variety is liable to be attacked by the pest.

The number of vascular bundles alone may not be of great value in determining the degree of resistance of a variety since ; though their number per unit area may be large, they may be very small with a poorly developed bundle sheath. This is the case in some of the susceptible varieties.

As lignification of tissues is an obvious factor in its hardness, the various resistant and susceptible varieties were next examined for this character. At first eight varieties, four resistant and four susceptible to the top-borer were taken up for study. Cross sections of the mid-rib were taken, stained in Safranin and Light green and permanent mounts made in Canada balsam. The total amount of lignification per unit area of the mid-rib was calculated as follows. The number of vascular bundles with the bundle sheath in one square millimetre of the mid-rib was drawn out on a paper with the help of a camera lucida. The area of the bundles was measured with a planimeter. This figure does not give the actual amount of lignification, as difference is noticed among the varieties in the thickness of the bundle sheath cells. So the area of the cavities or lumens of the cells in one square millimetre of the mid-rib was worked out. The total amount of lignification was obtained by finding the difference between the total area of the vascular bundles and the total area of the cavities of the sheath cells. The figures worked out brought out a distinct correlation between the two characters. All the four resistant varieties had a more lignified and better developed bundle sheath than in the four susceptible varieties (Plate XIII).

To find out whether there are any other anatomical factors correlated with the resistance of a variety, the following characters were also studied :

(1) The number of cork and silica cells per unit area of the lower epidermis of the mid-rib.
This character is of some importance since cork and silica cells contribute to the hardness of the mid-rib.

(2) The number of bristles per unit area of the lower epidermis of the mid-rib.
The more the number of bristles the less may be the chance of the larva attacking the variety since the bristles will offer resistance.

Peelings of the epidermis were taken by the method adopted by Artschwager [1930]. They were stained in chloro-iodide of zinc and the number of cork cells, silica cells and bristles per unit area calculated.

The amount of lignification in the mid-rib has been worked out for about fifty varieties. These include the different species of *Saccharum*, viz. *S. officinarum*, *S. spontaneum*, *S. Barberi*, *S. sinense* and *S. robustum* and interspecific and intergeneric hybrids between *Saccharum* and other general.

Observations

Table I gives the list of varieties and the amount of lignification for 100 sq. cm. of the mid-rib.

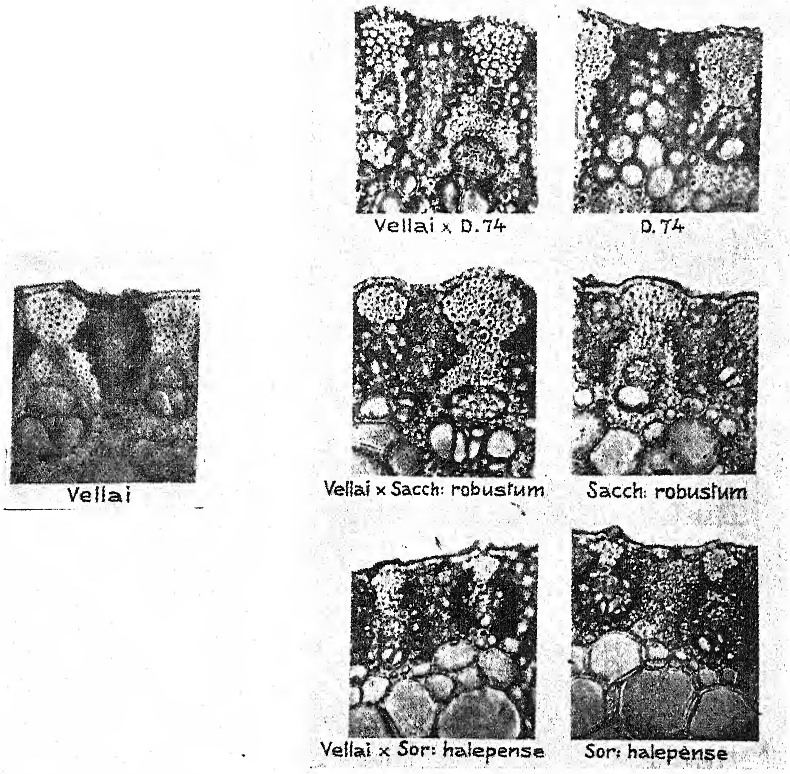
Absolutely according with the observation that the resistance of a variety depends on the intensity of lignification of the mid-rib, the examination of the data on the percentage of attack of the top-borer has shown that there is correlation between the degree of resistance of a variety and the amount of lignification in the mid-rib.

The figures in Table II demonstrate the relation between the lignification of the mid-rib and top-borer infestation in the varieties for which the percentage of dead hearts are available.

TABLE I

List of sugarcane varieties with the amount of lignification in their mid-ribs per 100 sq. cm. of the area of mid-rib

No.	Name of variety	Amount of lignification in sq. cm.
	SACCHARUM OFFICINARUM	
1	*Kaludai Boothan*	20·277±0·0525
2	*D. 74*	18·662±0·0491
3	*Vellai*	17·272±0·0925
4	*Black Cheribon*	16·928±0·0725
5	*Greensport*	16·917±0·0274
6	*Striped Mauritius*	15·468±0·0315
7	*B. 3412*	12·527±0·0794
	SACCHARUM SPONTANEUM	
1	*S. spontaneum*, Coimbatore	13·123±0·0925
2	*S. spontaneum*, Java	9·912±0·0524
	SACCHARUM BARBERI	
1	*Chunnee*	10·372±0·0721
2	*Saretha*	10·012±0·0675
3	*Katha*	9·312±0·0824
4	*Mungo*	9·311±0·0628
5	*Nargori*	9·279±0·0575
6	*Sunnabile*	9·112±0·0829
	SACCHARUM SINENSE	
1	*Uba*	10·155±0·0728
2	*Pansahi*	11·212±0·0825
	SACCHARUM ROBUSTUM	
1	*N. G. 251*	14·011±0·0529
	ERIANTHUS ARUNDINACEUM	
1	*Glongong*	15·862±0·0728
	HYBRIDS	
1	*Co. 205*	14·315±0·0675
2	*Co. 213*	10·525±0·0565
3	*Co. 214*	10·728±0·0665
4	*Co. 229*	9·825±0·0525
5	*Co. 244*	15·725±0·0785
6	*Co. 285*	18·674±0·0782
7	*Co. 291*	9·765±0·0594
8	*Co. 292*	12·822±0·0815
9	*Co. 312*	10·510±0·0357
10	*Co. 313*	10·414±0·0685
11	*Co. 318*	12·624±0·0578
12	*Co. 331*	20·010±0·0625
13	*Co. 356*	19·121±0·0545
14	*Co. 385*	10·218±0·0279
15	*Co. 395*	19·128±0·0712
16	*Co. 396*	10·107±0·0527
17	*Co. 419*	10·374±0·0725
18	*Co. 421*	20·715±0·0482
19	*P.O.J. 213*	13·911±0·0824
20	*P.O.J. 2364*	13·728±0·0725
21	*P.O.J. 2725*	14·712±0·0528
22	*P.O.J. 2878*	19·676±0·0948
23	*B.h.V* (Bamboo hybrid)	14·129±0·0595
24	*B.h.IX* (Bamboo hybrid)	10·917±0·0729
25	*Sorghum halepense*, Palestine	9·012±6·0628



Development of lignified tissue in a number of hybrids and their parents.

Table II

Correlation between the amount of lignification in the mid-rib and top-borer infestation

No.	Name of variety	Amount of lignification in sq. cm.	Percentage of dead hearts
1	*Co. 396*	10·017±0·0527	45·10±0·275
2	*Co. 385*	10·218±0·0279	42·20±0·321
3	*Co. 419*	10·374±0·0725	36·20±0·228
4	*Co. 312*	10·510±0·0357	36·10±0·225
5	*Co. 213*	10·505±0·0565	34·60±0·349
6	*POJ. 2878*	19·676±0·0948	21·10±0·531
7	*Co. 331*	20·010±0·0625	19·60±0·421
8	*Co. 421*	20·715±0·0482	18·30±0·258

From a study of the anatomy of the mid-rib of *Saccharum hybrids*, and their parents, evidence is available that this particular anatomical character, viz. marked lignification of the mid-rib can be inherited and passed on to the progeny by a suitable choice of parents. This will be clear from Table III wherein is given the area of lignified tissue per 100 sq. cm. in a certain number of hybrids and their parents (Plate XIV).

Table III

The area of lignified tissue in a number of hybrids and their parents

No.	Name of pistil parent with amount of lignification in sq. cm.	Name of hybrid with amount of lignification in sq. cm.	Name of pollen parent with amount of lignification in sq. cm.
1	*Vellai* Good lignification . . (17·272)	*Vellai* × *D. 74* Good lignification . (17·787)	*D. 74* Good lignification . (18·662)
2	*Vellai* Good lignification . . (17·272)	*Vellai* × *Sorghum* Moderate lignification . (13·142)	*Sorghum* Poor lignification . (10·175)
3	*Vellai* Good lignification . . (17·272)	*Vellai* × *Narenga* Good lignification . (16·827)	*Narenga* Poor lignification . (10·292)
4	*Vellai* Good lignification . . (17·272)	*Vellai* × *S. robustum* Good lignification . (18·072)	*S. robustum* Moderate lignification . (14·011)
5	*Vellai* Good lignification . . (17·272)	*Vellai* × *S. halepense* Poor lignification . (9·715)	*S. halepense* Poor lignification . (9·012)
6	*P.O.J. 2878* Good lignification . . (19·676)	*Co. 421* Good lignification . (20·715)	*B. 3412* Poor lignification . (12·527)
7	*Co. 213* Poor lignification . . (10·525)	*Co. 331* Good lignification . (20·010)	*Co. 214* Poor lignification . (10·728)
8	*Co. 213* Poor lignification . . (10·525)	*Co. 312* Poor lignification . (10·638)	*Co. 244* Fair lignification . (15·725)

The study of the number of cork cells, silica cells, and bristles per unit area in the epidermis revealed no correlation between any of these characters and the reaction of a variety to top-borer infestation. This study as at first confined to the eight varieties whose percentages of infestation is known, and when it failed to give any correlation, the study was not proceeded with for the other varieties. In Table IV is presented the average number of cork cells, silica cells and bristles per sq. mm. of mid-rib in the eight varieties together with the percentage of dead hearts.

TABLE IV

The average number of cork cells, silica cells and bristles per sq. mm. of mid-rib with the percentage of dead hearts

No.	Variety	Number of cork cells per sq. mm.	Number of silica cells per sq. mm.	Number of bristles per sq. mm.	Percentage of dead hearts
1	*Co. 396*	28±0·0674	10±0·0615	12±0·0835	45·10±0·275
2	*Co. 385*	15±0·0879	4±0·0389	5±0·0639	42·20±0·321
3	*Co. 419*	32±0·0749	3±0·0461	..	36·20±0·228
4	*Co. 312*	30±0·0853	10±0·0718	20±0·0640	36·10±0·225
5	*Co. 213*	27±0·0628	14±0·0788	16±0·0674	34·60±0·349
6	*POJ. 2878*	25±0·0520	6±0·0537	..	21·10±0·531
7	*Co. 331*	30±0·0769	4±0·0519	4±0·0492	19·60±0·421
8	*Co. 421*	35±0·1125	10±0·0369	20±0·0769	18·30±0·258

DISCUSSION

The above study and the collected figures prove that there is correlation between the intensity of lignification in the mid-rib of a variety and its resistance or susceptibility to the top-borer and that the top-borer infestation generally increases with the lessening of the lignification in the mid-rib. No variety seems to be completely immune to the attack of this pest and so the values are only comparative. Certain cane varieties are markedly more heavily infested by the top-borer than others.

Since it is the amount of lignification that decides the hard or soft nature of the mid-rib, the results of this study are in agreement with the view put forth by Isaac that varieties with strong mid-ribs are less liable to be attacked than those with soft mid-ribs 'and a strong mid-rib as a characteristic will afford the variety that has it, resistance to this serious pest'. It is obvious that the presence of good lignification in the mid-rib will make it hard and prove to be an obstacle to the entry of the larvae.

The resistant varieties have the bundle sheaths well developed and more prominent than the susceptible varieties. Thus in *Kaludai Boothan, Co. 331, Co. 356* and *Co. 421*, the bundle sheath is decidedly thicker and more prominent than in *Co. 213, Co. 313, Co. 419, Saretha*, etc. As already explained, the number of bundles alone is not enough to determine the degree of resistance of a variety. For example, in *Co. 419*, the number of bundles is greater than in *Co. 421* ; but the latter is twice more resistant to the top-borer because in *Co. 419* the bundle sheath is poorly lignified.

Generally the thick canes have a good amount of lignification in their mid-ribs, whereas the thin Indian canes have poorly lignified mid-ribs. So it may be predicted that the liability of infestation is likely to be greater in thin canes than in thick canes. From Table I it is clear that thick canes like *Kaludai Boothan, D. 74, Black Cheribon, Greensport*, etc., have very well lignified mid-ribs. The thin canes belonging to the various group under *S. Barberi* and *S. sinense*, viz. *Saretha, Katha, Mungo, Nargori, Pansahi*, etc. have poor lignification in their mid-ribs.

The wild *Saccharums*—especially the *spontaneums*—have been used to a great extent in breeding both at Coimbatore and Java as they have been found to be resistant to adverse environmental conditions and certain pests and diseases. The study of the mid-rib of some of these reveals that they have poorly lignified mid-ribs. Hence they may not be of use in breeding types resistant to this particular pest.

In *Sorghum* which has been used as one of the male parents in the intergeneric cross with sugarcane, the mid-rib is poor in its lignification. In bamboo which is the male parent in the sugarcane-bamboo crosses, there is a considerable amount of lignification in the mid-rib. Practically the whole of the mid-rib is lignified on both sides, thus making it very hard.

The studies have shown that this particular anatomical character, viz. good lignification of the mid-rib can be inherited. This will be clear from Table III. A good number of the hybrids has inherited this desired anatomical character. In some cases it is from both the parents as in the cross

between *Vellai* and *D. 74*, wherein both the parents and the hybrid have very well lignified mid-ribs. In some cases it is from one of the parents, as in *Co. 421* wherein the good lignification of *P.O.J. 2878* is noticed to the exclusion of the poor lignification in *B. 3412*. In some cases the hybrids have inherited the poor lignification of one of its parents, the good lignification of the other being not inherited as in the seedling of the cross *Vellai* × *Sorghum halepense*. In the case of *Co. 331*, the parents have poorly lignified mid-ribs, whereas it has a very well lignified mid-rib. This character has evidently been inherited from one of its remote ancestors, *Kaludai Boothan*.

Out of the two bamboo hybrids studied, *B.h.V* shows moderate lignification in its mid-rib whereas *B.h.IX* has a poorly lignified mid-rib. The hybrids did not inherit the very good lignification of the male parent. It is possible by back crossing the hybrids with bamboo to bring in the very strong mid-rib of the latter. In that case the hybrids might prove very resistant to the top-borer.

In the nature of inheritance of this anatomical character variation is met with even in hybrids which have the same female parent. In the crosses obtained with *Vellai* as female parent and with different male parents, some of the hybrids show good, some moderate and others poor lignification in their mid-ribs. This will be apparent from Table III and Plate XIV. This wide variation is characteristic of sugarcane hybrids and is to be expected since sugarcane is strongly heterozygous and each seedling a potentially new variety in itself. The question whether lignification of mid-rib is a dominant or recessive character cannot be answered with any degree of certainty due to the complex nature of sugarcane hybrids. Even in the F_1 generation it has been found that in one case, viz. *Co. 285* [*Saccharum officinarum* (*Vellai*) × *Saccharum spontaneum*, Coimbatore] the lignification is dominant, in another, viz. *Co. 291* [*Saccharum officinarum* (*Kaludai Boothan*) × *Saccharum spontaneum*, Coimbatore] it is recessive while in the third, viz. *Co. 205* [*Saccharum officinarum* (*Greensport*) × *Saccharum spontaneum*, Coimbatore], it is intermediate. The dominance or recessiveness of the character depends on the genetic background and the particular varieties used in combination. It could at best be said that the introduction of a parent with well lignified mid-rib, *i.e.*, hard mid-rib, increases the average hardness of the progeny. Since this much desired anatomical character is inheritable it is possible by suitable choice of parents to introduce into the hybrids this character and thus render them hard and resistant to the top-borer. Since the cheapest and efficient way of fighting out pests and diseases lies in the cultivation of resistant varieties, if such varieties with good lignification in their mid-ribs are brought into being by sugarcane breeders, it would be to the advantage of the sugarcane growers throughout the world.

Summary

1. The object of the present study is to find out whether any correlation exists between the resistance of a variety to the top-borer (*Scirpophaga nivella* F) and the hardness of the mid-rib.

2. About fifty varieties including the different species of *Saccharum* and the interspecific and intergeneric hybrids with *Saccharum* have been studied.

3. The results show that there is a fairly close correlation between the amount of lignification in the mid-rib (the hardness of the mid-rib) and the degree of resistance of a variety.

4. Thick canes generally have good amount of lignification in their mid-ribs, while thin canes have poorly lignified ones.

5. The good lignification of the mid-rib is found to be inherited from certain parents.

6. It might therefore be possible by a suitable choice of parents to introduce into the hybrids this desired anatomical character thus rendering the mid-rib hard and resistant to the pest.

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SEASONAL HISTORY AND FIELD ECOLOGY OF THE WOOLLY APHIS IN THE KAMAUN HILLS

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THE woolly aphis, *Eriosoma lanigerum* Hausman, a pest of apple trees all over the world, is believed to have been introduced into India on imported nursery stock. The first record of its occurrence in this country dates back to 1889 when it was observed damaging apple trees at Conoor in south India [Misra, 1920] and the next record appears to be its mention in the *Report of the Kamaun Government Gardens* for 1909-10, about which time it was also observed in the Simla district. Presumably the pest entered these localities much earlier. At present the woolly aphis is known to occur in several parts of the Indian region, viz. Kashmir, North West Frontier Province, the Punjab, the United Provinces, Assam, Burma, Sikim and south India.

Investigations on the woolly aphis in the Kamaun hills were started at Ramgarh, District Nainital, in 1929 and later, extended to Chaubattia-Ranikhet and other areas. The information collected during 1929-44 has been sifted and such of it as has appeared new or interesting is, in part, embodied in the present paper. Much of the biology of *E. lanigerum*, which is well known, has been omitted. A paper on the methods of controlling the pest in the Kamaun hills has been published by one of us [Singh, 1942].

The life history of the woolly aphis in Kamaun does not materially differ from that in the Punjab [Rahman and Khan, 1941]. The species is confined to apple trees only, is parthenogenetic, viviparous and multi-brooded. These broad facts also accord with the observations made elsewhere. In North America and Japan, however, elm is an important alternate host plant to which the woolly aphis migrates periodically and on which it reproduces sexually. Sexual forms of *E. lanigerum* appear in Europe and some other countries also but their progeny do not establish themselves well and hence are ineffective in aiding the multiplication of the pest. Fotedar and Kapur [1941], however, reported the occurrence of the sexual forms in Kashmir.

The woolly aphis, like other organisms, is a creature of its environment whose population is profoundly influenced by the nature of its host, natural enemies and climatic conditions. The mechanical action of wind and rain, however, appear to be negligible factors in determining the incidence or population of the pest. An attempt has been made in this paper to assess the relative values of these factors in terms of their effects on the woolly aphis population. Some observations have also been made to determine the varieties of apple, susceptible or resistant to woolly aphis attack, while a study of the behaviour of the species has thrown light on the apparent vagaries of its colonizing habits.

SEASONAL HISTORY AND HABITS

The woolly aphis attacks all aerial parts of the apple tree and, in some cases, also the parts a few inches below ground level. Adults and nymphs occur practically all the year round but during the coldest part of winter, that is, from the middle of December to the end of January, only nymphs remain, hidden in the cracks and crevices of the bark and other sheltered portions of the trees. During this period they are inactive, except that on sunny days a few of them may sometimes be seen moving from one shelter to another. They are, at this time, devoid of the waxy filaments on their bodies, as a result of which they are inconspicuous. Except for this temporary suspension of activities, there is no actual hibernation by the woolly aphis in Kamaun. Even if the apple trees are simply caged and thus some protection against cold is afforded to them, aphids of all stages remain active on them throughout the year, feed and move about and even show a certain amount of reproductive activity. In the Punjab, the woolly aphis is said to viviposit throughout the year [Rahman and

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Khan, 1941]. In Europe also it appears to have no 'true' hibernation [Greenslade, 1936]. In north America, however, the pest may hibernate in the egg and nymphal stages and, in warmer parts, oviparous females as well, on elm and apple trees [Metcalf and Flint 1939].

During February and March in Kamaun, the nymphs come out of their shelters, settle down at suitable places on the tree and start feeding. Soon after, the waxy filaments appear on their bodies and in about two weeks' time the adult stage is reached and viviposition commences. The newly born nymphs may remain close to their parents in the same colony or, if it is very crowded, may wander up and down in search of more favourable places to settle down and start new colonies. Viviposition goes on throughout the summer, autumn and early part of winter, after which it ceases; most of the adults die and the nymphs migrate to the under-ground parts or move into sheltered situations on the tree to tide over the coldest part of the winter as described before.

As happens in the Punjab, some of the aphids produced in early July are winged as also viviparous, parthenogenetic females like the wingless ones. Their number goes on increasing till about the middle of August when on a heavily infested tree the number of winged aphids may exceed that of the wingless ones. Some of the former fly to other trees and start new colonies but the progeny in such cases are usually wingless. The winged aphids gradually disappear after the middle of October. It was repeatedly observed that more winged aphids are produced on heavily infested trees than on those having fewer colonies. It is not possible to explain the precise relationship between over-crowding and the production of winged forms but, on the face of it, it appears to be a device of nature to aid in the dispersal of the aphids when once their original host trees have become over-crowded.

Migration from roots to shoots and vice versa

It has been the belief among the Kamaun orchardists that the woolly aphis migrates to the roots at the beginning of winter and crawls up to the aerial parts in early spring but this is only partially true. Actually a few nymphs can be observed migrating from the aerial parts to the roots and *vice versa* simultaneously all the year round and the pest persists on both, the aerial as well as the underground parts of the trees. In the Punjab, Rahman and Khan [1941] state that there is a definite, though partial, summer and winter migration at Raison and no migration whatsoever at Kulu (Sultanpur) proper.

With a view to collecting definite data regarding the movements of *E. lanigerum*, three groups of four trees each, with the aphids on shoots only, on roots only, and on both, shoots and roots, were marked out and grease-banded in May 1937 to observe the periods of their upward and downward movements. The trees, having colonies both, on shoots and roots, were grease-banded at two heights on the stem and the intervening distance was kept free of the aphids. Grease-banding was maintained throughout the following twelve months in perfect condition. Every band was examined twice a month and the aphids caught on each were counted and removed every time. The data collected during the twelve months are given in Table I.

An examination of Table I shows that, although the upward and down movements continue all the year round, there is a marked tendency for upward migration in summer and for downward migration in winter. At other times of the year the movements of the aphids appear to be indefinite. The data also indicate that, while upward and downward migrations are very probably influenced by the prevailing heat and cold, respectively, when such conditions tend towards the maximum, movements at other times are governed by other factors also than these climatic ones. Generally, only the nymphs migrate from one part of the tree to another.

Seasonal incidence

The intensity of infestation by *E. lanigerum* greatly fluctuates during the year. As soon as it starts reproducing in early spring, it is attacked by the predator, *Coccinella septempunctata* Linn., which preys on all of its stages [Lal and Singh, 1945]. In certain areas of Kamaun, this lady-bird is so effective that it hardly allows any colonies on the aerial parts of the trees between March and July. In others, infestation by the pest is generally light or heavy according as the lady-bird is scarce or abundant. After July, although the lady-birds leave the apple trees and migrate to grasses, there is not much increase in the number of the aphids as, during the rainy season, reproduction is

TABLE I

Monthly records of woolly aphis migration from shoots to roots and vice versa

—	Serial No. of Trees	March	April	May	June	July	August	September	October	November	December	January	February
		Number of migrating aphids											
Shoot to root	1	..	1	..	3	5	3	8	1	7	2	6	11
	2	16	..	..	4	3	..	..	6	19	20	23	11
	3	..	3	1	..	..	..	..	1	4	10	9	..
	4	..	..	..	17	..	..	17	2	3	8	..	..
Root to shoot	1	..	1	289	190	15	19	19	..	3	..	..	1
	2	10	..	69	112	63	1	38	225	131	..	..	67
	3	..	..	119	140	30	10	..	7	17	1	..	..
	4	..	..	43	47	..	2	2	35	266	12	..	2
Shoot to root	1	..	..	325	46	47	..	200	10	7	23	66	338
Root to shoot		..	100	2750	328	140	4	13	9	32	1	13	2
Shoot to root	2	..	..	172	88	52	3	8	6	88	64	1200	68
Root to shoot		..	5	825	165	500	300	..	61	69	5	..	56
Shoot to root	3	1	..	3	3	55	1	2	85	21	8	27	100
Root to shoot		14	5	11	15	171	9	3	200	212	2	93	33
Shoot to root	4	..	..	18	15	7	1	3	..	14	6	..	36
Root to shoot		..	..	383	1062	46	1	3	2	35	2	..	153

very slow due to climatic causes discussed hereafter. It is, therefore, mainly during October, November and part of December that the incidence of the pest is highest. During this period, the climatic conditions are not unfavourable for multiplication and the lady-bird is no longer there to exercise any effective check. As stated previously, from mid-December till early spring only nymphs occur.

Factors affecting seasonal history and incidence

(i) *Effect of atmospheric temperature and humidity*

Observations made at Chaubattia and at Ramgarh have indicated that the reproduction of the woolly aphis is not adversely affected by atmospheric temperatures up to 90°F., which is about the maximum attained in these parts. Reproduction, however, ceases when the mean minimum temperature goes below 37°F.

A monthly census of the population of the woolly aphis on three apple trees was taken during the years 1941 and 1942-43 at Chaubattia and Ramgarh, respectively. The method adopted was to divide a tree into a number of equal parts with regard to its infestation by the woolly aphis. One of these parts was again sub-divided into smaller portions of equal size and the number of colonies as well as the number of aphids in each colony in one of these sub-divisions were counted. The population of the aphids on the entire tree was determined by appropriate multiplications. The trees were caged to keep off predators but parasitization of the aphids by *Aphelinus mali* Hald. was possible. The data are presented in Tables II and III, wherein counts of both parasitized and unparasitized aphids are given. The data show that the maximum number of aphids was recorded in May and June when the maximum temperature went above 90°F. on several days, though the monthly average was lower. The gradual decline in the number of aphids from the end of June to about September appears to be due to increased humidity as after September, with the decrease in atmospheric humidity, the number of the aphids again increased. This decrease during the rainy season can not be attributed to high temperatures as these months were cooler than May or June. The colonies inside the cages were not directly hit by showers of rain and so there was no possibility of their being washed away by rain mechanically. Parasitism by *A. mali* also appears to have made little difference in the seasonal population of the aphids since the largest number of parasites inside the three cages was recorded in May and June when the aphis population was also the highest.

TABLE II

Population of woolly aphis in relation to atmospheric temperature and humidity in 1941 at Chaubattia

Month	No. of healthy aphids	No. of parasitized aphids	Averages of		
			Maximum temperature in F.	Minimum temperature in F.	Humidity (percentage)
March	150,400	7,520	66·06	50·90	39
April	(Observations not taken)		76·32	58·90	35
May	(Observations not taken)		77·20	59·60	56
June	552,960	123,420	74·72	61·18	84
July	346,066	80,286	74·96	62·71	84
August	275,576	52,084	71·90	62·00	91
September	146,260	20,842	68·70	58·45	80
October	467,190	42,935	68·10	53·79	73
November	232,100	26,447	58·70	45·00	57

TABLE III

Population of woolly aphis in relation to atmospheric temperature and humidity during 1942-43 at Ramgarh

Month	Tree No. 1.		Tree No. 2.		Averages of		
	No. of healthy aphis	No. of parasitized aphids	No. of healthy aphids	No. of parasitized aphids	Maximum temperature in F.	Minimum temperature in F.	Humidity (percentage)
April	6,699	1,168	28,812	2,486	76·60	52·30	44
May	21,060	1,252	44,880	11,505	82·60	56·20	41
June	37,720	2,338	32,604	4,302	84·50	..	58
July	1,680	350	23,970	4,753	77·00	61·00	84
August	3,230	658	5,184	825	75·20	62·20	86
September	1,408	371	2,967	724	75·10	55·80	74
October	1,512	230	3,192	425	75·50	47·30	58
November	2,744	617	1,819	492	72·20	41·70	58
December	3,024	591	1,634	420	58·80	35·50	59
January	(About the same number)				57·10	36·00	50
February	(About the same number)				61·40	38·50	60
March	(About the same number)				70·10	43·30	50

(ii) *Effect of natural enemies*

The woolly aphis in Kamaun is attacked chiefly by two predators: the larva of the Syrphid fly, *Syrphus confrater* Wied., and the beetle, *Coccinella septempunctata* Linn., and by the Eulophid parasite, *Aphelinus mali* Hald. The Syrphid larva is of little economic value but the lady-bird exercises considerable check on the pest in certain areas from early spring to the end of June [Lal and Singh, 1945]. As for the parasite, inspite of repeated attempts, it has not yet established itself in Kamaun and, therefore, its influence on the woolly aphis population has been so far negligible. An account of the behaviour of *A. mali* in Kamaun is being published separately.

(iii) *Varietal resistance of apple trees to woolly aphis attack*

In 1933, an area, containing over five thousand apple trees was marked out in an orchard at Ramgarh and every tree in that area was examined in October for woolly aphis attack The data are summarized in Table IV.

TABLE IV

Incidence of woolly aphis attack on some important varieties of apple.

Variety	No. of trees examined	No. attacked	Percentage of attacked trees	Intensity of attack*			
				I	II	III	IV
King of Tomkin's County	662	434	65·6	46·5	16·5	2·6	..
Blenheim Orange	634	530	83·6	60·4	22·3	0·9	..
King of Pipins	332	52	15·7	9·7	4·2	1·2	0·6
James Grieve	138	39	28·3	21·0	7·3	..	..
Delicious	193	12	6·2	6·2	..	..	..
Cox's Orange Pippin	183	70	38·25	31·7	6·5	..	.
Lanes Prince Albert	79	79	100·0	72·2	24·1	2·5	1·2
Jonathan	180	69	38·3	33·3	5·0	..	..
25 mixed varieties	5641	1993	35·3	24·3	9·4	1·3	0·3

* Explanation of intensity of attack:
I. 10-15 colonies on average-sized tree.
II. 16-40 colonies on an average-sized tree.
III. More than 40 colonies but the tree still looking healthy.
IV. Tree full of new and old galls and rendered very unhealthy.

Table IV shows that, although the percentage of very heavily infested trees is very low, quite a number of them are attacked by the pest. This number excludes the trees which had only a few colonies on them and did not appear to have been affected by the attack at all. Among the commercially important varieties, Blenheim Orange and King of Tomkin's County suffer the most. From general observations, carried out for many years, the important commercial apple varieties grown in Kamaun, may be classified in one of the four groups as indicated in Table V with regard to their susceptibility to the pest.

TABLE V

Classification of apple trees with regard to their susceptibility

Highly susceptible	Susceptible	Resistant	Highly resistant
Blenheim Orange	Cox's Orange Pippin	Delicious	Northern Spy
King of Tomkin's County	Norfolk Beefing	Alfruston	
Banoni	Esopus Spitzenberg	Golden Pippin	
King of Pippins (young trees only)	Newton	Rome Beauty	
	King of Pippins (grown-up trees)	Gano	

(iv) *Inter-action of apple stock and scion in regard to woolly aphis attack*

Le Pelley [1927] appears to be the only worker to attempt to discover if the resistance of apple stock to woolly aphis attack has any influence on the resistance of the scion worked on it. Although some of the varieties, used in his experiments as stock and scion, were not very true to the characters they represented, the results gave a fair indication to the effect that the resistance of the stock does not have a marked effect on the resistance of the scion. On the other hand, Jancke [1937] considered that the resistance of a variety is due also to an unexplained influence of stocks used for grafting edible apples. In order to obtain definite information on the subject, an experiment was conducted at Chaubattia, using only those varieties of apple whose degree of resistance to the pest was definitely known. The experiment is described below:—

Material and methods. Observations extending for several years on the relative susceptibility of most of the local and imported varieties to woolly aphis had shown Malling Type II to be highly susceptible and Merton 779 to be highly resistant. These two varieties, inter-worked as well as each grafted on itself, were planted in big tubs in the winter of 1938. Each treatment was replicated four times with one tree as the unit. All the trees were uniformly infected with woolly aphis several times between April and July 1939. Towards the end of August, large numbers of colonies developed on the aerial as well as the under-ground parts of some of the trees. At the end of October, the numbers of colonies formed on the roots and scion of each tree were counted.

The experiment was repeated in the two subsequent years and the results of the three years are summarized in Table VI.

Table VI shows clearly that the resistance or susceptibility of a variety is not affected by its union with another variety possessing the reverse characteristic. There is, however, an indication that the intensity of attack on a susceptible scion, worked on a resistant stock, is less than that on a susceptible stock. As also remarked by Greenslade [1936], this difference does not seem to be due to the imparting of any resistance to the scion by the resistant stock but to the freedom of the latter from the pest which may otherwise act as an additional and close source of infection to the scion. It follows, therefore, that by using an aphid-resistant stock the grower will not only be saved from the trouble of controlling the under-ground colonies but will also have less need to control the pest on the aerial parts.

TABLE VI

Incidence of woolly aphis on stock and scion during 1939-41

Name of scion/stock	Average No. of colonies on					
	1939		1940		1941	
	Scion	stock	Scion	stock	Scion	stock
Merton 779 / Merton 779	..	..	..	..	..	..
Malling Type II / Merton 779	4	..	22	..	7	..
Merton 779 / Malling Type II	..	4	..	48	..	46
Malling Type II / Malling Type II	10	8	51	17	28	23

(v) *Effect of different soils on the infestation of roots by the woolly aphis*

A pot culture experiment was carried out at Chaubattia to see if any of the three typical soils of the Government orchard, namely, clayey, sandy and humus-rich* made the plants more susceptible to root infection than others.

Material and method. Six plants of Malling Type II, a very susceptible variety of stock, were planted in big tubs, filled with each of the three types of the soils in the winter of 1937 (that is, 18 plants in all). Shoots of all the plants were artificially infected with the woolly aphis in April 1938. The aerial parts of all the trees became covered with colonies in about four months after infection by which time a few aphids also migrated to the roots and settled down there. The trees were allowed to grow till October 1939, when they were uprooted and the number of galls formed on the roots of each of them was counted.

The experiment was repeated in the two subsequent years and the average number of galls formed on the roots of each tree in the three types of soils is given in Table VII.

TABLE VII

Average number of galls on roots of plants in three types of soils during 1939-41

Year of observation	Clayey	Sandy	Humus-rich
1939	23·0	10·0	13·0
1940	1·3	1·2	7·0
1941	18·0	6·3	12·0

No definite conclusions can be drawn from the data given in Table VII. It is, however, indicated that in the first and the third years of the trial, comparatively more galls were formed on the roots in clayey soil than in others but there is no significant difference between any two soils in any year. As the aphid attacks the under-ground parts of the plant up to a few inches of depth only, the incidence of attack on the root system must depend on whether or not it is near to the surface. It has been observed that as the root goes deeper into the soil, the aphids leave it but the same root

may again be attacked lower down on the steep slopes if it comes near the surface or becomes exposed. Thus on steep slopes a root may be attacked on three or four isolated spots. It appears that root infection is dependent on good aeration of the top few inches of the soil. Therefore, a slightly heavier infestation in clayey soil may be due to the cracking of the soil, thereby allowing the aphids easy access to the roots and plenty of aeration.

Summary

1. The woolly aphis in Kamaun, as in the Punjab, is confined to apple trees and is viviparous, parthenogenetic and multibrooded.

2. The pest is active from March till about the middle of December. The maximum population is maximum in May and June and again in October, November and the first fortnight of December. After December mostly nymphs occur, concealed in cracks of barks and other sheltered situations on the trees. Winged aphids are produced during July and August which fly to other trees and start new colonies. Heavily infested trees show greater proportion of winged to wingless aphids.

3. Migration of the woolly aphis from shoots to roots and vice versa occurs practically all the year round. Upward and downward migrations are accentuated during the hottest and the coldest parts of the year, respectively. At other times, migrations appear to be independent of the weather conditions, being governed largely by the necessity of seeking suitable places to settle down.

4. The reporduction of the woolly aphis is not adversely affected by temperatures up to 90°F. Below 37°F., reproduction ceases. Excessive humidity, usually occurring during July-September retards the multiplication of the pest.

5. The woolly aphis in Kamaun is attacked by two predators, *Syrphus confrater* Wied. and *Coccinella septempunctata* Linn. The former is of little economic importance but the latter exercises effective check in certain areas from March to the end of June. Efforts at establishing the parasite, *Aphelinus mali* Hald., have not yet succeeded.

6. Observations are recorded on the behaviour of different varieties of apple trees to the attack of the woolly aphis.

7. Experiments on the inter-action of stocks and scions with respect to woolly aphis attack showed that the resistance or susceptibility of a variety is not influenced by its union with another variety possessing the reverse characteristic.

Acknowledgements

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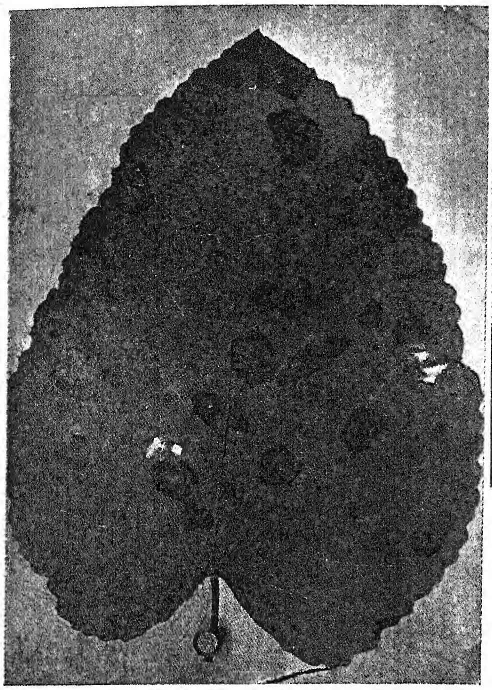

FIG. 1. Lesions (early stage) on the leaf of *Ficus carica*.

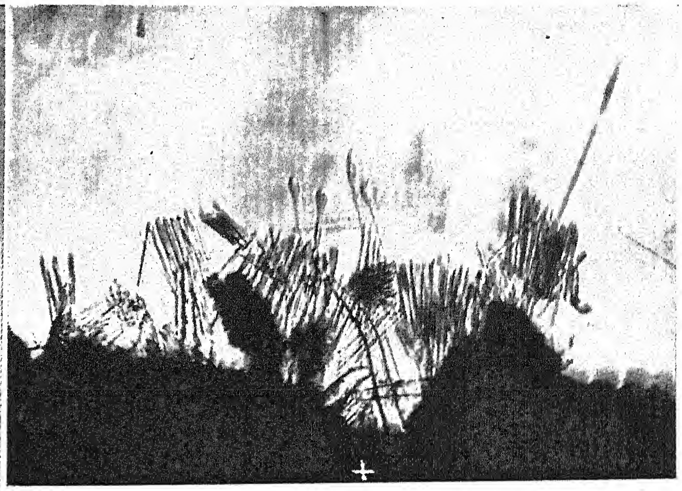

FIG. 2. Photomicrograph of the affected margin of leaf showing the spear like branches bearing bundles of conidia.

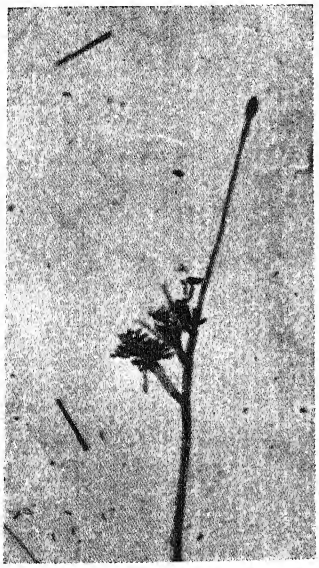

FIG. 3. Photomicrograph showing the structure of the spear like main branch with lateral monopodial branchlets (conidiophores)

FIG. 4. Section of a leaf showing a few conidia still attached at the tip of the monopodial branchlets.

FIG. 5. Chlamydospores.

A LEAF-SPOT DISEASE OF FIG (*FICUS CARICA* L.) CAUSED BY *CYLINDROCLADIUM SCOPARIUM* MORG

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(Received for publication on 6 February 1947)

(With Plate XV)

A LEAF-SPOT disease of *Ficus carica* L. was observed at Cawnpore, during 1945 in the rainy season. In 1946 the disease was again noticed at the beginning of July. The severity of the attack and the prominence of the lesions warranted investigation. Preliminary examinations revealed the presence of a fungus hitherto unrecorded from India. The fungus has been determined to belong to the Genus *Cylindrocladium*.

SYMPTOMS

At the commencement of the rains in the beginning of July, minute dot like brown spots up to 2 mm. across appear scattered on both surfaces of the leaf. These enlarge into prominent reddish brown spots measuring up to 30—40 mm. across. Sometimes the spots are partially limited by the veinlets, giving them an irregular appearance (Plate XV, fig. 1). The margin of the spots is dark brown and the colour is deeper where the margin happens to run along the veins. The veinlets within the patches are also prominently brown coloured. Some spots are light brown in the centre while others show a zonate appearance, especially on the upper surface. In most cases the spots coalesce and form irregular patches which may involve greater part of the leaf area. Shot-holes may appear in the centre of the old lesions. Sometimes the affected parts on the margin become brittle and break away. During humid weather the lower surface gets covered by a cobweb like mycelium which subsequently appears powdery. Infection was not noticed on other part of the host plant.

MORPHOLOGY OF THE FUNGUS

Mycelium. The mycelium is mainly intercellular. The hyphae are colourless, slender, septate and branched, and 3·5—6μ in diameter. Older hyphae tend to become brown. The affected cells turn brown and are killed giving rise to the typical spots. The xylem vessels are not usually penetrated but the vascular bundles become deep brown.

Conidia. In moist weather the affected areas produce, mostly on their lower surface, septate, erect, spear like main branch 230—355μ long and 3·5—6μ broad at the basal region and 1·4—2·8μ at their upper region. These come out singly or in clusters of 2—4 or more through the stomatal opening or directly through or between the epidermal cells. They are also produced on the aerial mycelium in the moist chambers. The apical cell of these main branches is characteristically swollen into a spear-head like structure, measuring 17—20μ by 7—10μ. These main branches bear one or more monopodial fertile secondary branches at various heights, mostly on the lower one-third part of their length. Viewed under the low power of the microscope these appear like slender, stalked, penicillate structures, each bearing a white shining head composed of a bundle of elongate conidia (Plate XV, fig 2). When mounted in water or lacto-phenol, the mature conidia get detached and their structure is then clearly seen (Plate XV, figs. 3 and 4). Each fertile branch is cymosely divided one to three times; the ultimate branch or the sterigmatum bears a cylindrical bicelled conidium (Plate XV, fig. 4). These lateral branches (or conidiophores) exclusive of the spores, measure 60—125 μ. Sometimes the spear like main branch is absent and only the penicillate fertile head is produced. Occasionally a lateral branch, ending in spear-like terminal cell arises from the main spear-branch and bears the fructifications. The bicelled conidia have rounded ends, measuring 32·4—50·4μ by 3·4μ at the apex and 3μ at the base. These germinate readily in water producing one germ tube from each of the cells; generally they come out of the ends but may be formed from any other part also. One of the germ tubes is produced earlier than the other.

Chlamydospores. In moist chambers sometimes the cells of the aerial hyphae swell up and become beaded. These enlarge and become light brown and form round or irregular chlamydospores up to 30μ in diameter. When kept in water they germinate by giving out germ tubes (Plate XV fig. 5).

Growth in culture

The fungus has been isolated in culture. On potato glucose agar it grows out uniformly forming a white circular colony and gradually becomes golden brown. The colour deepens and numerous sclerotia appear. The latter are composed of dark brown thick walled pseudoparenchymatous cells that resemble the chlamydospores in structure. The size of the sclerotia extends up to 0·8 mm. in diameter. At this stage chlamydospores are also seen under the microscope. These resemble those formed on the leaves kept in moist chambers and measure up to 40μ in diameter. None of these cultures have produced conidia even after one month.

Parasitism

The parasitic nature of the fungus has been established by inoculating both the surfaces of the leaves with conidial suspension obtained from the leaves kept in moist chambers for 24 hours, and also by putting bits of mycelium from the culture tubes and covering the latter with cotton pads moistened with sterilized water. The infection experiments were undertaken on humid and cloudy days during the month of August and September. More than 200 leaves were inoculated and about ninty per cent. of the leaves got readily infected by both the methods. Characteristic lesions were produced within seven days and the fructifications appeared after two weeks. The infected leaves are shed 20—30 days earlier than the healthy ones. Moist weather is essential for infection. It was also noted that the fully mature leaves are most susceptible. After October new leaves appear on the fig plants but these do not show any sign of the disease till the next rainy season. It thus appears that the fungus is a weak parasite attacking fully mature leaves which are in a low state of vitality prior to their being shed naturally after the rains.

Identity of the fungus

The Genus *Cylindrocladium* was first recorded and described by Morgan [1892]. Subsequently it was found on the dead leaves of papaw plant by Ellis and Everhart [1900]. The parasitic nature of the fungus was established by Massey [1917]. Recently the fungus has been recorded in England by Wormald [1944] on several members of the family Rosaceae. Anderson [1918] carried out detailed investigations on the morphology and parasitism of *C. scoparium* Morg. causing the crown canker of rose. The same author isolated another species from rose, *C. parvum* And., with smaller spores. Another new species of the genus *C. macrosporum* has since been recorded by Sherbakoff [1928] on a palm. Dodge [1940] has also recently reported a species *C. pteridis* on fern. Rea and Hawley [1912] had described and created a new genus *Candelospora*. According to Fawcett and Klotz [1937] the genus *Candelospora* resembles the genus *Cylindrocladium* in the structure of the fructification but differs from the latter in having three septate conidia.

The species appearing on *Ficus carica* has one septate conidia and the measurements of the conidiphores and conidia approximate the species *Cylindrocladium scoparium* Morg. The dimensions of the conidia given by the various authors are as follows:

Morgan (1892)	40—50 × 4μ at the apex, and 3μ at the base
Ellis and Everhart (1900)	40—50 × 4·5μ
Massey (1917)	36—55 × 3·3—4·51μ
Anderson (1918)	48·8 × 5·1μ
Wormald (1944)	41—64 × 4—6μ
Present authors on *Ficus carica*	32·4—50·4μ × 3·4 μ at the apex and 3μ at the base

The fungus causing the leaf-spot disease of *Ficus carica* is therefore *C. scoparium* Morg. So far this fungus has not been reported on the above host. This disease and the genus of the causal organism is a new record for India.

SUMMARY

1. During the rainy season a leaf-spot disease of *Ficus carica* L. was noticed at Cawnpore. The attack was severe and confined to the leaves.

2. Minute brown dots appeared on both surfaces of the leaves and enlarged into irregular spots. In most cases these coalesced and covered greater part of the leaf area. Shot-holes often appeared in the old lesions.

3. The hyphae of the fungus causing the disease was mostly intercellular, septate and branched. Characteristic spear-like branches came out of the surfaces of the leaves. Each had one or more monopodial secondary penicilloid branches with a bundle of bicelled, elongated, cylindrical and hyaline conidia at the tip. The conidia measured 32·4—50·4μ by 3·4μ at the apex and 3μ at the base. Chlamydospores were also observed.

4. The fungus was isolated in culture. Infection experiments on healthy leaves were conducted and fructifications appeared after a fortnight.

5. The identity of the fungus is discussed, and identified as *Cylindrocladium scoparium* Morgan. It is a genus hitherto unrecorded from India.

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THE ROLE OF 'CUTTINGS' IN THE DISSEMINATION OF FOOT-ROT OF PIPER BETEL

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(Received for publication on 27 November 1946)

FOOT-ROT, caused by *Phytophthora parasitica* var. *piperina* Dast., is the most serious disease of betel-vine in the Central Provinces and Berar. The disease was first reported in the province in 1923 and since then it has gradually increased with the result that at present the cultivation of the vines has been practically abandoned. In the early stages of infection external symptoms of the disease are general pallor, loss of lustre and drooping of tender shoots and leaves without any external sign of rotting or lesions on any of the aerial parts. Later on the whole plant turns yellow and dries off. Roots and underground parts of the stem rot and are destroyed. The disease has been found to be soil borne as well as 'seed' borne.

The dissemination of foot-rot through cuttings, so called 'seed', has so far not been systemically and thoroughly investigated. Mc Rae [1934] and Dastur [1935] are of opinion that the disease is soilborne but Chowdhry [1944] considers it to be seedborne as well, the pathogen being inside the cuttings. The experiments conducted by Chowdhry give only indirect indications as to the mode of dissemination, as neither the soil nor the cuttings were sterilized before planting. As such it could not be definitely concluded that the pathogen resides as dormant mycelium inside the planting setts and the disease is carried through them from place to place. It is probable that the fungus might have been carried externally on the cuttings or might have been present in the soil.

Continuous observations of several years in the past have shown that if an old garden is replanted, leaf-rot and foot-rot, both caused by *Phytophthora parasitica* var. *piperina* Dast., appear more or less simultaneously, after two or three months of plantation. If, however, a garden is raised on a land where betel-vine was never cultivated for several decades, leaf-rot invariably appears six or seven months earlier than foot-rot. It was further observed that the foci of infection for foot-rot were at places where leaf-rot appeared. In such cases the foot-rot infection spread along and across the betel-vine lines from the foci either due to falling of the diseased leaves on the soil below or due to the practice of lowering of the vines where they are first taken off the bamboo stakes, spread on the ground and then taken up and retied. In both the cases the fungus mycelium thus contaminating the soil, attack the roots of the vines and cause foot-rot. These observations gave an indication that in the case of replanting old gardens the infection was mostly from the soil, whereas in the gardens on soils without any previous history of *pan* cultivation the infection was mainly from the cuttings. In the latter case the fungus was carried by the cuttings and it first produced leaf-rot disease under favourable conditions of temperature and humidity.

The above observations were verified by conducting experiments in pots with sterilized soil. A year-old betel-vines of *kapuri* and *bangla* varieties were secured for seed purpose from a garden severely affected by the foot-rot disease. Each of these vines was cut from tip downwards into six pieces, each consisting of five or six internodes and measuring from 12 to 15 in. in length. In the text these pieces have been referred from tip downwards in order of succession as 1st, 2nd — — and 6th cuttings respectively. As per cultivation practices only three leaves were left on 1st to 4th cuttings while 5th and 6th were without leaves as they had none on them. Sixty unsterilized cuttings of each of the two varieties were sown as such on 4 November 1942, in pots with sterilized soil, one in each. In the other series, arrangements similar to the above were made but the same number of cuttings of the two varieties were sown after sterilizing them by dipping in 2 : 2 : 50 strength Bordeaux mixture for one hour. The experiments were duplicated and the observations were recorded every day for two years. The dates of the appearance of leaf-rot and foot-rot diseases in the unsterilized cuttings of both the varieties, *kapuri* and *bangla*, are given in Table I.

TABLE I

Dates of appearance of leaf-rot and foot-rot in unsterilized cuttings

Cuttings	No. of plants affected	Kapuri		Bangla	
		Leaf-rot	Foot-rot	Leaf-rot	Foot-rot
First	1	7-1-43	After 2 years	9-12-42	13-7-44
	2	11-1-43	5-7-44	21-12-42	After 2 years
Second	1	23-12-42	24-10-43	3-12-42	17-10-43
	2	3-1-43	23-12-44	11-12-42	After 2 years
	3	5-1-43	After 2 years	13-12-42	27-7-44
	4	11-12-43	17-3-44	19-12-42	After 2 years
Third	1	7-1-43	After 2 years	17-12-42	13-11-44
	2	17-12-43	do.	7-1-43	12-2-44
Fourth	1	17-12-42	2-8-44	7-12-42	27-9-43
	2	11-1-43	29-4-44	9-12-42	After 2 years
	3	..	..	13-1-43	do.
	4	..	..	27-1-43	7-8-44
Fifth	1	Did not appear	2-9-43	Did not appear	2-7-43
	2	do.	11-9-43	do.	21-7-43
Sixth	1	Did not appear	19-2-43	Did not appear	11-2-43
	2	do.	23-2-43	do.	21-2-43
	3	do.	3-3-43	do.	23-2-43
	4	do.	28-3-43	do.	5-3-43
	5	do.	4-7-43	do.	28-3-43
	6	do.	11-7-43	do.	7-7-43
	7	do.	3-8-43	do.	11-8-43
	8	do.	5-8-43	do.	13-8-43
	9	do.	9-8-43	do.	27-8-43
	10	do.	11-8-43	do.	27-8-43

It will be observed from Table I that in the first four cuttings of both the varieties leaf-rot disease always appeared earlier than foot-rot. All the ten plants raised from the 6th cuttings and two of the 5th of each variety died due to foot-rot disease though there was no incidence of leaf-rot. The first incidence of leaf-rot was recorded just after a month of sowing while foot-rot appeared after three months and the infection went up to 45 per cent within five months.

In the second series, where the cutting were treated with 2 : 2 : 50 strength Bordeaux mixture for one hour before sowing there was not a single case of leaf-rot disease in any of the cuttings. The 1st, 2nd, 3rd, and 4th cuttings were neither affected by leaf-rot disease nor by foot-rot. Three plants raised from the 5th cutting, one of *kapuri* and two of *bangla*. were osberved to be affected only by foot-rot disease on 13-7-43, 27-7-43 and 21-8-43 respectively. This effect was more pronounced in the plants raised from 6th cutting where foot-rot disease appeared in all the plants and killed them. The first appearance of foot-rot disease in the plants raised from the 6th cutting was after three months of sowing while in the 5th cutting after eight months.

From the above experiments it could, therefore, be inferred that in the case of 1st to 4th cuttings, which are generally used for 'seed' purposes, the pathogen was borne externally and not carried internally, as otherwise after surface sterilization they should have given foot-rot disease as in the 6th cutting. Further, it was found that *Phytophthora parasitica* var. *piperina* Dast. is also carried internally in the lowermost cutting, mostly in the last one, as in spite of surface sterilization the foot-rot disease appeared just after three months of sowing. It may, however, be mentioned that in actual cultivation practice the lowermost two or three cuttings of the vines are never used for 'seed' purposes as the vines from these remain stunted in growth and do not produce leaves of any economic value. The first four cuttings give luxurient growth and the vines yield leaves which fetch high price

in market. When these cuttings were treated with Bordeaux mixture (2 : 2 : 50) for an hour before sowing they did not exhibit any sign of leaf-rot or foot-rot diseases as mentioned above, thus indicating that the pathogen was not carried internally but only externally. The untreated cuttings were affected by both the diseases, first by leaf-rot and later by foot-rot, the former appearing after a month of sowing and the latter on the same affected plants after a duration of seven months to two years. In such cases the pathogen was carried externally, invariably on leaves, causing leaf-rot, and these infected leaves spread the infection to the soil when they fell on it, which in its turns attacked the roots of the vines causing foot-rot. The roots were invariably attacked least one inch below the ground level. The leaves and roots were attacked by fungal mycelium and artificially the parasitism could be established in cent per cent cases. Repeated thorough searches could not reveal the presence of zoospores on roots, stems and leaves. Fungal mycelium could be invariably observed internally in the 6th cuttings, rarely in the 5th and never in the first four cuttings.

I am thankful to Mr. K. A. Mahmud, B. Sc., for his help during the course of this study.

SUMMARY

1. Both foot-rot and leaf-rot diseases of betel-vine are caused by *Phytophthora parasitica* var. *piperina* Dast.

2. Cuttings obtained from an infected garden when planted in a new *bareja* first give leaf-rot which is followed by foot-rot. Both the diseases appear practically simultaneously if an old garden is replanted. In the first case the foot-rot disease is due to infected cuttings while in the latter it is caused by the infected soil as well as by the cuttings.

3. The pathogen is disseminated by cuttings from place to place ; it being borne only externally in the first four top cuttings and internally as well in the lower ones.

4. The dissemination of the leaf-rot and foot-rot diseases to new gardens can be effectively controlled by the use of only first four cuttings and by treating them with 2 : 2 : 50 strength Bordeaux mixture for one hour before planting.

5. Cuttings should not be taken below five feet from the top of a vine as in an infected garden the fungus mycelium is carried inside the tissue of the lower cuttings.

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DETERMINATION OF PRESSURE IN SEALED CANS BY THE SPHEROMETER

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(Received for publication on 2 December 1946)

(With two text figures)

IN EXPERIMENTS on the preservation of food in sealed cans it is often necessary to determine the change in pressure inside the cans. The change may be caused by the formation of hydrogen gas, spoilage due to yeasts or any other cause. Sample lots of about half dozen cans are drawn at random from the experimental pack, after different periods of storage, and pressure is determined with a gauge after piercing the can cover. The cans thus opened served once, and once only, so far as the development of pressure in the pack is concerned. What is actually obtained is the pressure in a number of cans opened after varying intervals, or stored long enough to reach a condition where half the cans showed swelling due to pressure. From this the condition of the pack is inferred. The method is obviously defective because the initial vacuum, which is of primary importance, is not known except in cans opened at the time of packing and which are no more a part of the pack. Further due to great variation in the condition of the tinned surface, individual cans give out different amounts of hydrogen and consequently develop different pressures, even when headspace is the same in all cans. The ideal thing would be to know the pressure in all the experimental cans, at the beginning, during, and at the end of the storage period. To attain this object, Adam and Stanworth [1934] suggested the use of the spherometer. The original paper was unobtainable, but a reference to it in a later publication [Adam, 1942] was seen and a method developed independently. After this work was almost completed Adam [1943] has given further details about the method. But neither is the method of measurement completely described, nor are any figures given to enable the reader to find out the pressure in any set of cans. The simple method developed in these laboratories is, therefore, described.

Pressure develops most commonly only in fruit packs because of the highly acidic nature of the contents. As the size most popular with the fruit packers in India and abroad, is A2, figures for this size only have been obtained. The bigger size (A2½) is also used to some extent; but inclusion of figures for both sizes would have increased the statistical work too much for this short paper. For those interested, the method given points the way as to how figures can be obtained for any other size which they may be using. The dimensions of the two sizes mentioned are well known to the trade but are given here for ready reference.

TABLE I

Dimensions of the two can sizes

Size No. (cylindrical)	Height in inches		Diameter in inches		Capacity in c.c.	Remarks
	Inner	Outer closed	Internal	External at the rim		
A2	4·3	4·4	3·2	3·4	550	Tin plate of 100 lb. 'substance'
A2½	4·5	4·6	3·9	4·1	750	

The apparatus used is shown in Fig. 1. It consisted of a can A of which the two ends were properly closed and a copper tube 15 mm. long and 5 mm. bore was soldered at the middle of the cylindrical portion. The can was connected through a mercury manometer B and stop cock C to a larger bottle in which pressure could be raised or lowered at will. A plane glass plate with a 10 mm. hole in the centre was placed on the can. By placing a spherometer on the glass plate, the distance between the lower plane of the glass plate, (i.e. the upper plane of the rim of the can) and the centre of the

can cover was determined. Another reading was taken for the other side by inverting the can. The sum of the two readings was called the distance of the can cover from the plane of the rim. This is briefly referred to as "the distance" in the remainder of this paper. The spherometer was sensitive to 0·0025 mm. but readings were taken correctly only up to 0·005 mm. (*i.e.* one division on

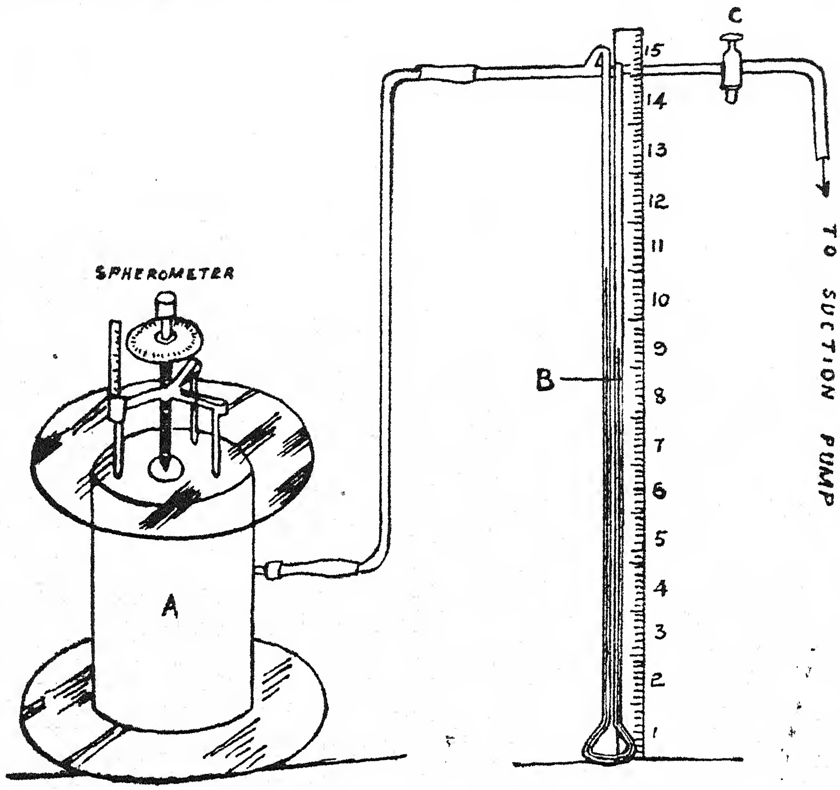


Fig. 1

the spherometer disc) because the variations due to other causes are much larger than this and it was thought unnecessary to take the readings more accurately. The legs of the spherometer were placed symmetrically with regard to the expansion rings so that the spherometer screw contacted, as near as possible, in the centre of the cover. The point of contact was determined electrically with a battery and a bell. One of the electric wires was placed under the can and the other momentarilly brought in contact with the spherometer to see if contact had been established. By varying the pressure in the can from 12 inches above to 12 inches below that of the surrounding atmosphere twenty-five readings of distance were obtained for each can. Twenty-three A2 cans were studied. The mean distance (in microns) at different pressure is given in Table II.

Only the mean distance of the cans is given, because mention of all the 23 cans would give 23 such tables. However, statistical analysis of the cans was done individually also, but the variation among cans for the same pressure was of a much lower order of magnitude compared to the differences caused by the pressure. At zero pressure difference, the variation of distance among cans was insignificant compared to the change by one inch increase, or decrease, of pressure. This shows that, the standard can closing machinery gives the same type of can, so far as the distance of the covers from the plane of the rim is concerned.

The standard deviation of the distance is shown in the third column. The variation between cans in response to change of pressure is apparently of the same order up to a pressure of six inches above the atmospheric pressure. After this the covers begin to yield more rapidly to the pressure and slight differences in the seams of the thickness of the plate are likely to cause greater variations

among the cans. These latter were compared by the test and it was found that one inch change of pressure caused a significant variation in the distance at all pressures except the atmospheric pressure where the value is the lowest, though still significant. Table II further shows that the movement of the cover is much greater on the pressure side than on the vacuum side. This result is to be expected because of the greater restriction in the movement of the cover to the inside than to the outside.

TABLE II

Mean distance in A2 can and change caused by 1 in change of pressure at various pressures

Difference from atmospheric pressure in inches of Hg.	Distance (microns)			Change of Distance		
	Mean of 23 cans	Standard deviation	Calculated	Mean	S. E.	t
—12	9713	15·9	9657	..	..	..
—11	9637	16·0	9608	76	3·1	24
—10	9564	16·0	9535	73	4·9	14
— 9	9491	14·1	9497	73	5·1	14
— 8	9413	15·2	9433	78	3·8	20
— 7	9330	14·2	9365	83	4·3	18
— 6	9263	13·9	9291	67	5·4	12
— 5	9179	13·1	9213	82	4·0	20
— 4	9096	13·1	9130	83	3·8	21
— 3	9009	13·3	9042	87	2·7	31
— 2	8918	11·7	8049	91	4·6	29
— 1	8820	14·2	8841	98	6·7	14
0	8752	12·2	8747	68	7·7	8
+ 1	8683	13·8	8683	110	11·2	6
2	8583	14·6	8526	121	4·6	23
3	8452	14·5	8408	129	6·1	19
4	8323	15·3	8286	132	4·9	26
5	8191	16·7	8158	142	4·8	27
6	8049	16·2	8025	145	6·7	21
7	7904	17·0	7884	158	5·7	25
8	7746	21·5	7744	165	10·7	15
9	7581	21·7	7597	159	8·1	19
10	7422	25·1	7444	159	11·9	14
11	7263	26·4	7286	159	6·8	23
12	7104	32·3	7124	157	10·0	15

The values of mean distance are plotted in Fig. 2.

The figure shows clearly the trend stated above that with increase of pressure above that of the atmosphere the curve diverges from the pressure axis. This characteristic property clearly indicates that the curve is anything but linear as stated by Adam in his latest publication [1943]. His conclusion is based only on the vacuum half of the curve. Increasing the range has brought out the true form of the curve. In fact this could be guessed from the following reasoning. As the vacuum increases, the time would come when the cover would cease to move inward, and conversely, as the pressure increases to 14-15 inches in case of A2, and to 7-8 inches in case of A2½ cans, there is a sudden rapid movement of the covers, the can bulges and what is known as doming takes place. This is the same as to say, that the curve tends to become parallel to the pressure axis as the vacuum increases and to the distance axis as the pressure increases. Taking pressure as independent and distance as the dependent variate, the method of the orthogonal polynomials was applied for fitting an equation to the curve. The sums of squares contributed by linear and quadratic regression are given in Table III.

Quadratic regression was significant. The equation connecting the distance with pressure was :

$$Y = 8747 - 105{\cdot}5X - 2{\cdot}5x^2 \quad \text{.......(i)}$$

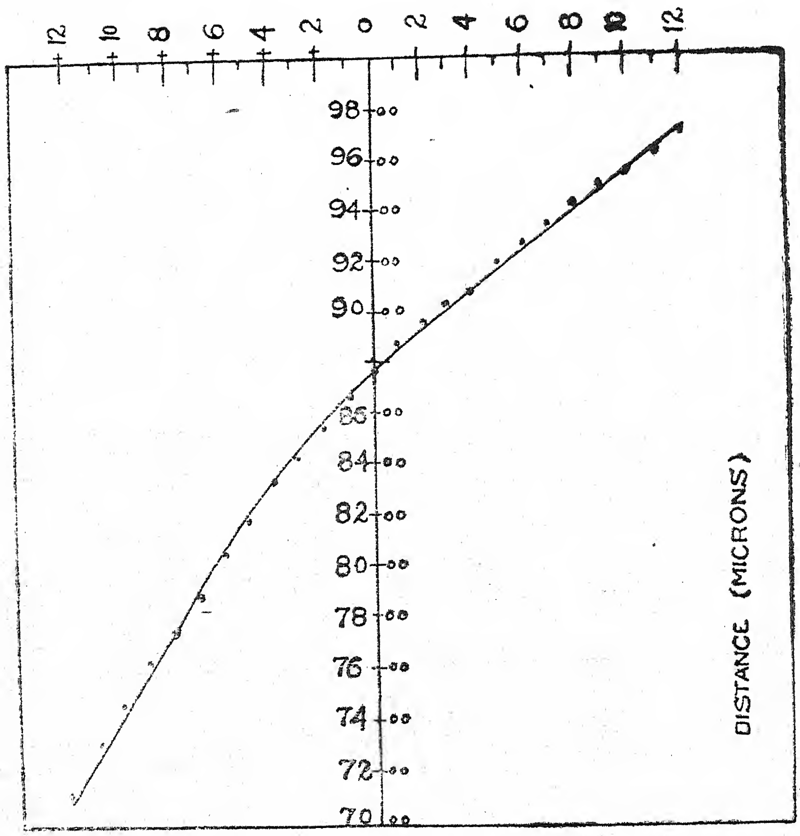
where Y is the distance (in microns) as defined above and x is the pressure difference, in inches of mercury, between the inside of the can and the surrounding atmosphere. The calculated values of the distance are given in the fourth column of Table II and are shown as black dots in Fig. 2. After

taking the reading for distance of any sealed can, the pressure can be read off from Fig. 2, or calculated more exactly, by the equation :—

$$X = \sqrt{944{\cdot}2-0.4y} - 21.1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

which is another form of equation (i). Only the positive value of the square root is to be taken for the calculation.

In order to test the accuracy of the method in practice a dozen cans were taken at random from a large lot and the distance measured. The pressure was then determined by the gauge method. The results are shown in Table IV. The agreement is reasonably good and the method can, therefore, be expected to give good results.



PRESSURE DIFFERENCE FROM ATMOSPHERIC (INCHES OF MERCURY)

Fig. 2.

TABLE III

The sums of squares contributed by linear and quadratic regressions

Variance due to	D. F.	Sum of squares	Mean square
Linear regression	1	14,482,828	14,482,828
Quadrate	1	330,851	330,851
Residual	22	22,713	1,032
Total	24	14,836,392	..

Significant at 1 per cent level

TABLE IV

The observed and calculated pressure in sealed cans

Serial No.	Distance in microns	Pressure calculated	Pressure found by gauge
1	8115	5	6·0
2	10245	—12	—11·5
3	10130	—12	—10·5
4	8320	4	4·0
5	9220	—6	—3·0
6	9455	—8	—6·5
7	8460	3	0·0
8	9575	—10	—9·5
9	9690	—12	—11·0
10	8610	2	2·0
11	7785	8	9·0
12	8770	0	0·0

SUMMARY

1. A procedure is suggested by which the relation between the pressure in a can and the distance between the plane of the rim and centre of the can cover can be determined. Only A2 cans have actually been studied, but the method is applicable to other similarly made sizes.

2. After statistical analysis and equation has been suggested for determining pressure from a reading of distance. The equation will be quadratic for other sizes also. Only the constants will be different.

3. Determination in a random lot has shown good agreement between observed and calculated results and the method can be recommended when large lots of cans are to be observed over long periods for a tendency to develop pressure due to hydrogen or fermentation.

ACKNOWLEDGEMENTS

The author wishes to thank S. B. Lal Singh, now Fruit Development Adviser to the Government of India, for his interest in the work while he was head of the Fruit Section in this Institute and to Mr. D. N. Nanda, Statistical Assistant to the Cotton Research Botanist for helping in the Statistical analysis.

REFERENCES

Adam and Stanworth (1934). *Annual Report of the Fruit and Vegetable Preservation Research Station. Campden*, 74 (*not seen*)

Adam (1942). *Ibid*, 10

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REVIEW

THE USE OF HETEROSIS IN THE PRODUCTION OF AGRICULTURAL AND HORTICULTURAL CROPS

By T. ASHTON, Imperial Bureau of Plant Breeding and Genetics publication—July 1946. Price 3s.

THE production of hybrid maize and its success in different parts of the United States of America constitute an achievement of very great importance. The exploitation of heterosis, which has engaged the attention of a number of workers, offers great economic possibilities in many crops including some self-pollinated ones.

The author of the bulletin has brought together the results obtained by different workers engaged in the study of heterosis with special reference to its utilization in agricultural and horticultural crop production. It is very difficult to deal in detail with all the work done on different crops in a small treatise like the one in question. The author has, however, presented a good deal of useful information which enables the reader to have an idea as to how heterosis can be exploited for commercial purposes.

The cost of seed production is one of the chief factors on which the commercial utilization of the phenomenon depends and, as such, its value is very limited in normally self-fertilized crops in which one flower produces one seed and artificial hybridization is difficult or laborious. The author has done well to mention the work carried out by different investigators to overcome these difficulties by attempting to find out male-sterile forms or by bulk emasculation as has been tried in Sorghum. Growing of bulk seed of some later generations has also been tried in a few cases.

Besides an introductory section wherein a mention has been made of the different explanations put forward by various workers for the phenomenon of heterosis, the bulletin is divided into four sections dealing with self-pollinated crops, cross-pollinated crops, a sexually-propagated plants and forest trees. Within each section, crop plants are treated individually. The extensive bibliography should be of help to all workers in the field.

The bulletin will be welcome to all those engaged in the practical application of hybrid vigour since no general publication on the subject has so far been available.—B. P. P.

PLANT QUARANTINE NOTIFICATIONS

Notification No. F.4-6/47-PP(SV), dated the 17th May 1947, of the Government of India in the Department of Agriculture

IN exercise of the powers conferred by Sub-section (1) of Section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following further amendment shall be made in the notification of the Government of India in the late Department of Education, Health and Lands, No. F. 320/35-A, dated the 20th July 1936, namely :—

In the First Schedule appended to the said notification in column 3 for the words 'The Department of Agriculture' against the entry 'Holland' in column 2 the words 'The Director of Plant Protection Service at Wageningen' shall be substituted.

EXTRACT

Health certificates in respect of plant imports from Holland (Country of Origin) will in future be issued under the authority of 'The Director Plant Protection Service at Wageningen' and not of 'Department of Agriculture' as indicated in the first Schedule to Destructive Insects and Pests Act, 1914.

MGIPC—NS—III-1-14—19-6-48—600.

ORIGINAL ARTICLES

INVESTIGATIONS ON THE RED LEAF DISEASE IN AMERICAN COTTONS*

I. RED LEAF DISEASE IN SIND-AMERICAN COTTONS IN SIND

By R. H. DASTUR† and KANWAR SINGH, Indian Central Cotton Committee, Bombay

(Received for publication on 10th December 1946)

THE reddening of leaves in American cottons has been reported to occur ever since this type of cotton was introduced in India. Burt and Haider [1919] reported this phenomenon in Cawnpore-American cottons in the United Provinces, and later the same 'disease' was reported by Kottur [1920] from Dharwar and by Prayag [1927-28] from Khandesh. The reddening of leaves was also found to occur in the Punjab during the years when cotton crop failed in that Province [Milne, 1921 and 1922]. It was found to be present by Sawhney [1932] in Deccan Hyderabad. The red leaf 'disease' was also of common occurrence in Sind [Dabral, 1938]. It was also found to occur in the American Upland cottons grown in Central India [Rao and Wad, 1936]. Thus it was a 'disease' appearing in all parts of India where American cottons were grown.

As the red leaf in *hirsutum* cottons has been reported to occur under different conditions of soil and climate, it is possible that the causes that give rise to this common symptom in the leaves may be different. The leaves of *hirsutum* cottons have a tendency to redden whenever they become senescent either prematurely or at the end of the life cycle. It was, therefore, necessary to determine the different conditions under which this 'disease', as it is generally called, occurs.

The red pigment in the leaves of *hirsutum* cottons is also found to develop as a result of injury caused by Jassids [Sawhney, 1932]. The injury causes the death of leaf tissues and the red pigment subsequently develops. This investigation describes the red leaf that occurs in the absence of Jassid injury.

Rao and Wad [1936] have concluded that this 'disease' was caused by the bad soil conditions during the monsoon period in Malwa tract. They have also reported a higher osmotic pressure of the soil solution surrounding the diseased plants as compared with the osmotic pressure of the soil solution surrounding the healthy plants. Numerous determinations of the soluble solids in the soils from near the 'diseased' and healthy plants during this investigation revealed no differences that could account for such wide differences in the osmotic pressure.

Dabral [1938] had differentiated the red leaf 'disease' into different types of which one was caused by a deficiency of nitrogen and this was cured by the application of various fertilizers containing nitrogen. It will be shown below that yellowing and not reddening was a symptom of nitrogen deficiency, and that reddening was an after-effect that followed yellowing. In many cases reddening after yellowing did not occur. It has already been shown [Dastur, 1939 and 1941] that yellowing of leaves that occurred in the Punjab-American cottons in the Punjab was caused by a deficiency of nitrogen in light sandy soils where the development of the red pigment was not found to be of general occurrence.

INVESTIGATION

The red leaf 'disease' has been investigated in two tracts: (1) Sind and (2) Central India, where the soil and climatic conditions were quite different. The results so far obtained in Sind have been summarized below. It may be stated here that the work on the red leaf disease in American Uplands under rain-fed conditions in the Central India is at present in progress.

The most important American cotton growing tract is situated in the lower part of Sind where the acreage under American cotton is nearly 75 per cent of the total acreage of cotton in the province. This region includes the Tharparkar district and the southern part of the Hyderabad district. American cotton is also grown in the upper part of Hyderabad district and in Nawabshah district

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* This investigation was financed jointly by the Indian Central Cotton Committee and Sind Government
† Formerly Professor of Botany, Royal Institute of Science, Bombay

on the Left Bank of the Indus river. Very small areas are under American cottons on the Right Bank in Dadu and Larkana districts.

The yellow-red leaf disease in Sind-American cottons mainly occurs in south Sind which is the most important cotton tract in Sind. This trouble appeared to be more frequent and widespread in this tract than in any other tract. In fact it was found to be present every season.

The previous findings of Dabral [1938] were based on the work done at Sakrand which is situated in Nawabshah district in middle Sind where the red leaf is neither acute nor so widespread. It was, therefore, considered necessary to conduct the investigations in Tharparkar and Hyderabad districts where this 'disease' was of common occurrence. The climatic conditions in south Sind are known to be different from the climatic conditions prevailing in middle Sind and it therefore appeared likely that this difference in the climatic conditions may be associated with the more widespread and a common occurence of the ' disease ' in the former tract.

Observations made on the cotton crop in Sind during the cotton season of 1942-43 showed that the reddening occurred in two ways and this difference has been, on further investigation, found to be of such great importance that the red leaf has been classified into two main types. In one type the change in colour of the leaf from green to red takes place through the intervening stage of yellowing. The leaves first turn pale and yellow before the red pigment develops. In this type of reddening, the leaves sometimes turn deep red or scarlet in colour. In the second type the change in colour from green to red occurs without the intervening stage of yellowing. The leaves in such cases turn bronze or copper coloured. The two types can be distinguished from a distance. Both the types have been found to occur in the different parts of the same block of land in Sind.

The analysis of the soil samples taken from the spots where these two types of red leaf occurred revealed important differences in their physical properties (Table I).

TABLE I

Mechanical analysis of the soil under yellow-red and green-red Sind American cottons

Depth in feet	Yellow-red			Depth in feet	Green-red		
	Clay per cent	Silt per cent	Sand per cent		Clay per cent	Silt per cent	Sand per cent
1st foot	7	14	76	1st foot	24	30	46
2nd foot	11	17	72	2nd foot	37	32	31
3rd foot	9	26	64	3rd foot	43	40	17
4th foot	9	34	56	4th foot	45	45	10
5th foot	15	39	45	5th foot	48	46	6
6th foot	23	54	42	6th foot	48	44	8

The soil under yellow-red type was light sandy containing a very high percentage of sand and low percentage of clay while the soil under green-red type was heavy containing low percentage of sand and high percentage of clay.

The physical texture of Sind soils varies inbetween the two limits given above and it would be difficult to distinguish the yellow-red from the green-red when the proportions of sand and clay of fractions are inbetween these two extremes. It was, however, noted that the yellow-red type was distinguishable when the soil was composed of about 60 per cent or more of sand and 8 to 12 per cent of clay. Under lesser proportion of sand fraction yellowing prior to reddening could not be properly distinguished.

YELLOW-RED LEAF IN SIND-AMERICAN COTTONS

It was experimentally proved in the cotton season of 1943-44 that the yellow-red leaf occurred on account of a deficiency of nitrogen in such light sandy lands. A light sandy field where the red

leaf was reported to occur in previous seasons was selected at Denisar Estate, Nabisar Road, Sind. A sowing date-cum-manurial experiment consisting of eight randomized blocks of four main plots each, for four different sowing dates was laid out. Each main plot was split into two sub-plots for control and 33 lb. N per acre treatments. Nitrogen was applied in the form of sulphate of ammonia on the 5th June. The variety was L.S.S., a Punjab-American variety grown on this estate.

Observations on the crop showed that the leaves turned first pale and later red during the fruiting period in the months of August-September in the unmanured plots of the first two sowings while it was green in all the manured plots. The yellow-red leaf generally occurred at a much later date in the 3rd and the 4th sowings of the unmanured plots. Manuring was also found to have a beneficial effect on yields but the increase in yield caused by manuring became less and less as the sowing date advanced (Table II).

TABLE II

Yield in maunds per acre

	Sowing date					
	23/3	6/4	20/4	4/5	Mean	S.E.
Manured	18·1	19·1	17·0	14·5	17·2	±0·50
Unmanured	11·7	13·5	14·1	13·2	13·1	
Mean (±0·76)	14·9	16·3	15·6	13·9	15·2	

Another similar experiment to study the effect of the application of sulphate of ammonia on the yellow-red leaf in Sind-American cottons in light sandy land in the middle Sind was laid out in the same season at the Agricultural Research Station, Sakrand. Though the fields select d were light sandy there were saline patches scattered irregularly all over the area. The experiment consisted of three randomized blocks of 12 main plots each in which all combinations of four sowing dates (14th May, 3rd June, 24th June, 17th July) and three nitrogen treatments (control, 40 lb. N per acre in the form of sulphate of ammonia at sowing and 40 lb. N per acre in the form of sulphate of ammonia at flowering) were randomized. Each main plot was split for four varieties (M4, Sind Sudhar, 289F/K25 and 289F/124). Thus it was intended to study the effect of the early and late application of the manure on the development of the red leaf in the case of two Sind-American (M4 and Sind Sudhar) and two Punjab-American varieties (289F/K25 and 289F/124).

The yellowing of the crop was first noticed in the month of September in the first sowing while it did not appear in the fourth sowing in the unmanured plots. The manured plots showed no yellowing except in the case of the first sowing where yellowing developed in October indicating that the dose of nitrogen applied did not prove adequate to prevent yellowing in the early sown crop. It was also noticed that though there was yellowing of the leaves there was very little leaf reddening in this experiment. The crop was however very patchy in most of the plots on account of the presence of alkali or saline patches. In such patches the crop did not show yellowing.

There was a significant increase in the mean yield of all varieties as a result of late application of sulphate of ammonia. The early (at sowing) or the late (at flowering) application of the fertilizer proved equally effective in increasing the yield of two early maturing varieties M4 and 289F/124 while the late application of sulphate of ammonia proved more efficacious than the early application in the case of two late maturing varieties, Sind Sudhar and 289F/K25. Thus application of sulphate of ammonia lessened the yellowing of leaves and increased the yields. It also increased the seed maturity as the boll weight determinations showed (Table III at B). There was significant increase in boll weight (*i.e.*, seed cotton per boll in gm.) in manured plots and late application was found to give the maximum increase in boll weight.

Further experimental evidence to show that a low nitrogen content of the leaves was associated with the yellow-red leaf was obtained in the cotton season of 1944-45. A common experiment on sandy fields at three places, viz., Nabisar Road, Hyderabad and Sakrand was laid out. It consisted of all combinations of two sowing dates, two levels of nitrogen (0, 50 lb N at flowering) and two spacings ($s1 = 2$ ft. and $s2 = 2\frac{1}{2}$ ft. between rows). Each plot was split to accommodate three varieties M4, Sind Sudhar, and L.S.S. In order to correlate the yellow-red leaf with nitrogen content, fortnightly leaf samples from two replications of all the 24 combinations in the experiment at two centres, viz., Nabisar Road and Hyderabad were taken. Four plant sample under wide spacing and eight plant sample under close spacing were taken at random in duplicate. The leaves were analyzed for nitrogen. Regular observations were recorded on the appearance of the red leaf under each treatment at the time of sampling. The results of nitrogen contents of the leaves are given in Table IV.

The study of the results of the nitrogen contents of the leaves in relation to the time of appearance and the spread of the yellow-red leaf at the two centres disclosed in general terms the following relationships between the yellow-red leaf and the nitrogen contents of the leaves under different treatments.

M4 on the whole showed the least yellowing and reddening of the leaves while L.S.S. showed the symptoms at a very early stage and in a very intense form. The crop of M4 remained green even in the unmanured condition up to the end of the fruiting season while L.S.S. showed yellowing and reddening even in the manured plots of the first and in some cases of the second sowing. The concentration of nitrogen in the leaves of M4 remained significantly higher at each stage of growth than the concentration of nitrogen in the leaves of the other two varieties. The leaves of L.S.S showed the least concentration of nitrogen (Table IV). Thus yellow-red leaf appeared to be definitely related to the nitrogen concentration in the leaves.

The manured plots of all the varieties showed much less yellowing and reddening than the corresponding unmanured plots during the fruiting period. These symptoms appeared only in the leaves in some of the manured plots of the first sowings of L. S.S. or Sind Sudhar. The concentration of nitrogen in the leaves of the manured plots was also found to be significantly higher at each stage of growth than the concentration of nitrogen in the leaves of the control plots (Table IV).

The late-sown crop generally showed less yellowing and reddening than the crop sown early. The concentration of nitrogen in the leaves of the late-sown crop was found to be significantly higher at each stage of growth than the concentration of nitrogen in the leaves of early-sown crop.

It was clear that yellowing and reddening of the leaves in American cottons in Sind was associated with a low concentration of nitrogen and was a symptom of nitrogen deficiency. It may be stated here that the selection of plants for analysis of the leaves was at random. The plants were first randomized and then taken for analysis at each date. The term yellowing-reddening used above does not necessarily mean that each and every plant in a plot or all the leaves of a plant had turned yellow-red. Though the general appearance of the crop in a plot indicated yellowing, some leaves of some of the plants may be green or pale green.

The above mentioned conclusions regarding the relation of nitrogen content and the yellow-red leaf were further supported by the yield data obtained in the common experiment (Table V).

M4 gave the highest yield both under manured and unmanured conditions at all the three centres. It had the highest nitrogen content and was found resistant to yellow-red leaf. Manuring gave substantial increases in yields varying from 2·62 to 5·40 maunds per acre. It has already been shown above that manuring had increased the nitrogen content and had at the same time decreased the red leaf.

Explanation of the frequent occurrence of the red leaf trouble in south Sind

The complaints of red leaf were generally received more frequently from southern parts of Sind than from middle Sind. The yellow-red leaf was found to be generally present in many fields in the former tract. How can the greater prevalence of this trouble in the southern parts of Sind be explained if nitrogen deficiency in light sandy soil was the root cause of this trouble as light sandy lands were as widely distributed in middle Sind as in south Sind ? The red leaf trouble was found to be

TABLE III

Effect of the application of sulphate of ammonia on yellow-red leaves

	A Yield in maunds per acre			
	Control	Sulphate of Ammonia before sowing (40 lb. N per acre)	Sulphate of ammonia at flowering (40 lb. N per acre)	Mean (±0·51)
M4 . . .	11·0	13·7	13·5	12·8
Sind Sudhar .	9·8	10·4	13·1	11·1
289F/K25 .	9·8	11·7	14·3	11·9
289F/124 . .	9·7	12·7	13·2	11·9
Mean (±0·85) .	10·1	12·2	13·5	

	B Weight of seed cotton per boll in gm.			
	Con-trol	Sulphate of ammo-nia before sowing (40 lb. N per acre)	Sulphate of ammo-nia flower-ing (40 lb. N per acre)	Mean (±0·092)
M4 . .	2·65	2·93	2·93	2·84
Sind Sudhar .	2·22	2·36	2·49	2·35
289F/K25 .	2·54	2·58	3·05	2·72
289F/124 .	2·71	2·78	2·83	2·77
Mean (±0·102)	2·53	2·66	2·82	

TABLE IV

Mean percentage nitrogen in leaves on different dates at two centres

Denisar

Date of sampling	Varieties M4	Sind Sudhar	L.S.S.	S.E.
28th July	3·22	2·96	2·83	0·041
13th August . . .	3·08	2·87	2·75	0·047
29th August . . .	2·51	2·30	2·21	0·035
14th September . .	2·21	1·88	1·74	0·058

Date of sampling	Nitrogen Manured	Control	S.E.
28th July	3·32	2·68	0·052
13th August . . .	3·31	2·49	0·055
29th August . . .	2·66	2·03	0·062
14th September . .	2·14	1·75	0·058

Date of sampling	Sowing date Late sowing	early sowing	S.E.
28th July	3·11	2·89	0·052
13th August . . .	3·22	2·58	0·055
29th August . . .	2·50	2·19	0·062
14th September . .	2·12	1·78	0·058

Hyderabad

Date of sampling	Varieties M4	Sind Sudhar	L.S.S.	S.E.
23rd July . . .	3·47	3·19	2·96	0·028
7th August . . .	3·14	2·91	2·70	0·020
23rd August . . .	2·66	2·46	2·50	0·022
7th September . .	2·31	2·07	1·87	0·022
23rd September . .	1·79	1·64	1·47	0·031

Date of sampling	Nitrogen Manured	Control	S.E.
23rd July . . .	3·39	3·02	0·035
7th August . . .	3·03	2·80	0·034
23rd August . . .	2·78	2·29	0·043
7th September . .	2·28	1·88	0·029
23rd September . .	1·70	1·56	0·034

Date of sampling	Sowing date Late sowing	Early sowing	S.E.
23rd July . . .	3·49	2·92	0·035
7th August . . .	3·18	2·65	0·034
23rd August . . .	2·85	2·22	0·043
7th September . .	2·38	1·78	0·029
23rd September . .	1·79	1·47	0·034

even of less frequent occurrence in the Punjab than in middle Sind even though there are vast areas in the Punjab which are light sandy.

TABLE V

Yield in maunds per acre

—	Denisar		Hyderabad		Sakrand		Mean		Increase due to manuring
	Control	Manured	Control	Manured	Control	Manured	Control	Manured	
M4	10·36	14·17	14·67	18·84	11·55	15·66	12·19	16·23	+4·04
Sind Sudhar	7·56	8·94	11·06	14·61	9·89	15·20	9·50	12·92	+3·42
L.S.S.	8·86	11·50	12·38	17·91	7·98	14·75	9·74	14·72	+4·98
Mean	8·92	11·54	12·70	17·12	9·80	15·20	10·48	14·62	+4·14
Increase due to manuring	+2·62		+4·42		+5·40		+4·14		
S.E. (Varieties)	±0·251=2·45 per-cent		±0·326=2·19 per-cent		±0·695=5·58 per cent				
S.E. (Nitrogen)	±0·502=4·91 per-cent		±0·549=3·68 per-cent		±0·587=4·71 per cent				

Further investigations conducted on this problem have revealed that the widespread occurrence of yellow-red leaf in southern parts of Sind was a result of the interaction of soil factor with the climatic factors prevailing in that tract.

Two Sind-American varieties, M4 and Sind Sudhar, and one Punjab-American variety, L.S.S., were grown at three centres in south Sind (Denisar Estate, Nabisar Road), in middle Sind (Sakrand) and in the Punjab (Iqbal Nagar). A common sowing date-cum-varietal experiment was laid out at the three centres. Though the object of the experiment was to study the growth of these three varieties under different sowing dates and under the climatic conditions prevailing in the three tracts, the observations made on the onset and the completion of the reproductive phase provided evidence for the cause of such frequent and widespread occurrence of the yellow-red leaf disease in south Sind. During the above mentioned study regular observations on the initiation and the completion of the reproductive phase of each of the three varieties at the three centres were recroded with a view to determine the main flowering period and the harvesting period. It was expected to provide information regarding the relation of climatic factors with the initiation and the completion of the reproductive phase of a variety. The main flowering and harvesting periods at the three centres for each variety are given in Table VI.

TABLE VI

Main flowering and harvesting periods of the three varieties at the three centres

	South Sind (Denisar Estate)	Middle Sind (Sakrand)	Punjab (Iqbal Nagar)
	(a) Flowering periods		
M4	17th July to 17th August	10th August to 10th September	16th August to 13th September
Sind Sudhar	5th August to 15th September	20th August to 20th September	23rd September to 19th October
L.S.S.	30th July to 30th August	25th August to 20th September	15th September to 15th October
	(b) Harvesting periods		
M4	September to October	October to December	October to December
Sind Sudhar	Mid-September to early November	November to January	November to January
L.S.S.	do.	do.	do.

In south Sind there was an early initiation of flowering and setting and early completion of the fruiting phase and consequently early finishing of the crop. The general pickings in this tract started by the first or the second week of September and were almost completed by the end of October or beginning of November at the latest while in middle Sind and the Punjab the pickings began by the second or the third week of October and were almost complete by the end of December. The crop finished off more quickly, *i.e.*, in less than two months, in south Sind than in middle Sind and in the Punjab. This difference in the setting and maturation of the crop could be explained by the differences in the climatic conditions prevailing in these tracts and these will be pointed out below.

Earliness or lateness of a variety is its inherent character but it can be modified by the climatic factors, as has been clearly brought out by this investigation. An early maturing variety may become late in a different environment and vice versa. L.S.S. which is a late maturing variety in its natural environment in the Punjab became early when grown in south Sind. It flowered, fruited and finished off earlier in the latter tract than in the former tract and in middle Sind (Table VI). Similarly M4 which is an early Sind variety became comparatively late under the Punjab and middle Sind conditions. Thus the inherent character of earliness or lateness could be shifted forward or backward by climatic conditions even though the relative differences between an early and a late variety would still persist in a given environment (Table VI). M4 always matured earlier than L.S.S. in south Sind or in the Punjab while L.S.S. always matured later than M4 in the same two tracts (Table VI).

The differences between the flowering and the harvesting periods in south Sind on one hand and the middle Sind and the Punjab on the other hand could be explained on the basis of the differences in the maximum and minimum temperatures and humidity prevailing in these tracts (Table VII).

TABLE VII

Monthly means of maximum and minimum temperatures and humidity

——	April	May	June	July	August	September	October	November	December	January
				South Sind (Hyderabad)						
Maximum . .	102·0	107·2	104·2	99·2	95·9	97·4	97·9	89·1	79·0	76·2
Minimum . . .	72·1	78·2	81·7	80·9	79·0	76·2	70·1	58·9	52·3	50·6
Humidity at 8 A.M. .	47	54	62	68	70	68	56	52	55	57
				Middle Sind (Sakrand)						
Maximum . .	102·0	111·0	110·0	104·0	102·0	102·0	101·0	89·0	78·0	74·0
Minimum . . .	67·0	77·0	83·0	83·0	80·0	75·0	65·0	54·0	46·0	43·0
Humidity at 8 A.M. .	53	53	63	71	73	74	68	69	76	73
				Punjab (Multan)						
Maximum . .	97·9	106·9	108·3	104·3	101·2	100·5	95·9	84·8	73·5	69·7
Minimum . . .	68·4	78·1	84·2	84·3	82·6	77·5	65·1	53·5	45·0	43·3
Humidity at 8 A.M. .	47	42	50	63	68	65	56	60	69	71

There was an early fall in the maximum temperature from the month of July in south Sind and it remained lower throughout the remaining part of the season. The minimum temperatures were throughout higher during the fruiting and maturation period (August — October) in south Sind while in middle Sind and the Punjab the later part (October — December) of the fruiting and maturation period was characterized by a rapid fall in the night temperatures. The differences between maximum and minimum temperatures are also of a lower magnitude in south Sind. These differences in temperature between south Sind and middle Sind and the Punjab may be responsible for the early initiation, setting and maturation of the crop in the first tract, as explained below.

The fall in the maximum temperatures in July in south Sind gave rise to an early initiation of fruiting branches. High temperatures as shown by Balls [1919] retard the stem growth as well as the formation of flowering branches. The fruiting branches are not formed as soon as the temperatures

drop but its effect becomes visible after a lapse of certain period from the day the temperature begins to fall. The lower temperatures in August in south Sind also helped in the setting of bolls. As there was no great fall in the night temperature which remained well above 70°F. during the bolling and maturation period, the bolls matured very rapdily. As a result of numerous determinations it was found that the maturation period of bolls for all the three varieties generally varied from 33 to 39 days. The crop therefore became early and finished off early, before the night temperatures fell below 70°F.

In middle Sind and the Punjab the temperatures began to fall in August and the initiation and the setting of the crop began to occur from the middle of August or the beginning of September according to early or late habit of a variety. The maturation period of bolls coincided with falling night temperatures. The night temperatures in October fell below 70°F. and they were still lower in the months of November and December (Table VII). Consequently maturation occurred at a slower rate so much so that the maturation period of bolls increased from 45 days to 70 days. The maturation period of bolls of all varieties was found to increase from 40 days in the bolls set in August to 70 days for bolls set in October. The late set bolls continued to open up till the end of December or beginning of January in the late maturing varieties.

The entire flowering period in south Sind was also found to be comparatively shorter than in the Punjab and consequently the boll formation also ceased earlier. This may be an additional factor that contributed to an early finishing of the crop in south Sind.

Though no differences in humidity recorded at 8 A.M. were found to exist in the three tracts during the reproductive phase, the humidity during the day was known to be higher in south Sind than either in middle Sind or the Punjab. It is also likely that higher humidity during the day may minimise abscission and may thus cause an early setting of bolls. Thus higher humidity may also contribute to an early setting and thus indirectly to an early maturation of the crop.

It has already been shown by the senior author [Dastur and Ahad, 1941 and Dastur, 1941] that the nitrogen content of the leaves began to decline when the reproductive phase set in and the leaves began to turn pale and yellow when their nitrogen content fell to 1·5 per cent of the dry matter of the leaves. The rapid maturation of the crop in south Sind brought about a quick depletion of nitrogen in the leaves and the nitrogen content of the leaves, therefore, fell much below that level when yellowing started. The nitrogen contents of Sind Sudhar and L.S.S. under unmanured condition had fallen to 1·5 per cent as early as the first week of September (Table VIII) in the April-sown crop. The drain of nitrogen in the leaves was so great that young and mature leaves along with old leaves were found to turn pale and yellow. The nitrogen content of the leaves on manured land remained much above 1·5 per cent during the maturation period and consequently yellowing did not occur even though the crop matured equally rapidly.

The cotton crop under middle Sind and the Punjab conditions matured slowly on account of a fall in temperature in October and there was, therefore, no such rapid depletion of nitrogen from the leaves. The nitrogen content of the leaves of 4F remained above 1·5 per cent up to the end of November. It was higher even in the month of November in the Punjab than in the month of September in south Sind in the May-sown crop (Table VIII).

The yellowing, therefore, occurred in the Punjab towards the end of the maturation period except on light sandy lands. On the latter type of land yellowing occurred towards the end of September and it was found to be accompanied with a low nitrogen content in the leaves.

Conclusions

The yellowing and the subsequent reddening in *hirsutum* cottons in Sind, therefore, occurred on account of the operation of two factors : (1) light sandy lands deficient in nitrogen and (2) higher night temperatures during the fruiting period causing a rapid maturation of the crop. In the Punjab and middle Sind yellowing occurred on account of the operation of the soil factor alone. Light sandy soils are widely distributed in all the three tracts but quick maturation of the crop in south Sind on

TABLE VIII

Percentage of nitrogen in leaves in south Sind and the Punjab

Date	Hyderabad (south Sind)						Date	Lyallpur (Punjab)	
	Sown on 15th April			Sown on 22nd May				Sown on 14th May 4F	Sown on 21st June 4F
	M4	S.S.	L.S.S.	M4	S.S.	L.S.S.			
23rd July . .	2·65	2·32	2·29	3·76	3·29	3·07	24th July . .	3·78	4·42
7th August . .	2·56	2·07	2·00	3·33	3·22	2·89	8th August . .	3·16	3·40
23rd August . .	2·32	1·83	1·89	2·14	2·08	2·09	22nd August . .	2·78	3·37
7th September .	1·95	1·55	1·49	2·14	1·87	1·77	5th September .	2·39	3·25
23rd September .	1·65	1·30	1·15	1·88	1·46	1·46	19th September .	2·33	2·69
							3rd October . .	2·46	2·72
							18th October . .	2·24	2·37
							1st November .	1·73	2·35
							15th November .	1·88	2·13

account of the prevailing higher night temperatures at that time caused the trouble to spread on lands which were not very deficient in nitrogen, i.e., it spread to lands where normally the premature yellowing did not occur under Punjab conditions. The red leaf trouble was, therefore, more widespread in south Sind than in the other two tracts. The variations in the nitrogen status of the soil from field to field caused variations in the intensity and the time of its appearance. The intensity and the spread of the red leaf trouble can also increase in south Sind if the month of September was characterized by spells of higher temperatures than normal as they would further hasten the maturation process and quicken the depletion of nitrogen from the leaves. Wherever there was quick depletion of nitrogen, the entire plant turned yellow-red while wherever the depletion was not so quick, some leaves turned yellow and some remained normal. The time of appearance and the intensity of the yellow-red leaf trouble would also be influenced by the previous crop, by manuring and by fallowing.

The remedial measure for minimising the yellow-red leaf in Sind American cottons in south Sind along with the method to be adopted for giving practical effect on *zamindars'* lands will be described in the next contribution.

SUMMARY

As the red leaf in American upland cottons (*G. hirsutum*) has been reported to occur from different parts of India where the soil and climatic conditions are known to vary greatly, it appeared that the causes that give rise to this symptom of reddening may also be different. It was, therefore, undertaken to investigate the problem in the irrigated tract of Sind and the rain-fed tract of the central India. The present paper deals with the investigations conducted in Sind.

Two types of reddening depending on the physical properties of the soil have been discovered; one type in which the change in colour occurs from green to yellow and then to red and the second type where the change is direct from green to red. These are two extremes between which intermediate stages in the two types of reddening may be found.

Complete experimental evidence has been produced to show that the yellow-red leaf was caused by a deficiency of nitrogen in the leaves of plants growing on light sandy lands. The leaves of plants which showed this type of reddening during the fruiting phase contained significantly less nitrogen than the leaves of plants which were green in colour.

M4 which showed these symptoms in the least degree was found to contain higher concentration of nitrogen in the leaves at each stage of growth than the leaves of L.S.S. and Sind Sudhar which suffered most from this 'disease'.

The plants manured with sulphate of ammonia did not show the yellow-red leaf while the symptom was found to be present in the unmanured plants in the same field.

Late sown crop showed less yellow-red leaf than the early sown plants and the nitrogen concentration was higher in the former than in the latter.

In addition to the amelioration of yellow-red leaf, manuring significantly increased the yields of seed cotton per acre.

The more frequent and widespread occurrence of the yellow-red leaf in south Sind than in middle Sind and in the Punjab even though sandy lands are common in all the three tracts, has now been explained. The addition to the soil factor, viz., sandy nature of the soil, the climatic conditions in south Sind operated in the widespread occurrence of the yellow-red leaf in that region. On account of an early drop in the temperature in July there was an early initiation of flowering. Higher day humidity in this tract reduced abscission and favoured setting of bolls. The maturation period in August, September and October coincided with high night temperatures which hastened the boll development. A large number of determinations revealed that the maturation period of bolls varied from 33 to 39 days. The crop finished off in two months, i.e., in September—October. In the Punjab there was late initiation of flowering in September on account of very high temperatures in July and August and the fruiting period therefore coincided with falling night temperatures in October, November and December. The maturation period of bolls was found to vary from 45 days to 70 days. The crop finished off at the end of December or the beginning of January.

The rapid maturation of the crop in south Sind caused heavy depletion of nitrogen from the leaves which consequently became senescent, turned yellow and red. Thus the red leaf trouble was accentuated and it spread to lands where normally this 'disease' did not appear under middle Sind and the Punjab conditions.

A practical method of locating such fields where this trouble is likely to occur is being worked out and will be reported in the next contribution.

Acknowledgments

The authors' grateful thanks are due to Mr. Y. Subba Rao for the nitrogen analysis of the leaves reported in this investigation. Thanks are also due to S. Sucha Singh and S. Mukhtar Singh for their co-operation in conducting field experiments.

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MANURIAL REQUIREMENTS OF RICE IN THE CENTRAL PROVINCES

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(With Plates XVI and XVII)

IN the report on the work of the Imperial Council of Agricultural Research in applying science to crop production in India, Sir John Russell recommended that more systematic schemes of manurial trials were necessary in order to test the relative values of nitrogen in artificial fertilizers, farmyard manure and composts, and the values of phosphate and potash. Acting on these recommendations, the sub-committee on field and manurial experiments, at its meeting held in November 1938, recommended standard designs for manurial experiments on rice to be carried out at different centres. Experiments on the effect of nitrogenous and phosphatic fertilizers alone and in combination, and on organic and inorganic manures and their mixtures were started at the Rice Research Station, Raipur, in 1939 and were continued for five years. Investigations on the effect of oil-cakes and compost were begun in 1942 and have been continued for three years. The results of these experiments are summarized in this paper.

PREVIOUS WORK

The results of manurial experiments on rice carried out at Government farms, Raipur, Waraseoni and Jubbulpore, prior to 1930, have been reviewed by Allan [1932]. These trials have shown that both cattle-dung (6,000 lb. per acre) and green manure Sunn hempor *Crotalaria juncea*, (8,000 lb. per acre) are very effective in bringing about significant increases in yield over no manure and the addition of phosphates (2 cwt. bone-meal per acre) considerably increases the efficiency of bulky organic manures. Green-manuring, however, is restricted to areas where irrigation before the monsoon is an economic possibility and this renders the practice unlikely to have any widespread application.

On the lighter soils the application of soluble phosphoric acid (1 cwt. superphosphate per acre) is profitable and distinctly more effective than bonemeal. In absence of phosphoric acid, the effect of nitrogenous fertilizer (ammonium sulphate) is barely significant.

The application of Nicifos II at 180 lb. per acre is profitable.

The results of manurial experiments on rice conducted in the Provinces and States of India during 1932-38 have been analyzed in the publications of the Imperial Council of Agricultural Research [Vaidyanathan, 1938] and have been brought together in the form of a bulletin by Sethi [1940]. Sukhatme [1941] has presented a test of significance for profit which has been adopted in this paper.

EXPERIMENTAL RESULTS

Experiment 1 (a)—Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of paddy. Soil—Heavy, Dorsa (clay loam)

Design. The experiment was a 3×3×3 factorial design with four replications, each replicate having 27 treatment combinations. Three sub-blocks of nine plots each were used in each replication, confounding 2 degrees of freedom with block differences.

Treatments (rates of application). The factors employed were—

Nitrogen at three levels—0, 10 and 20 lb. per acre, in the form of ammonium sulphate (20 per cent N.).

Phosphoric acid at three levels—0, 10 and 20 lb. per acre, in the form of double superphosphate (40 per cent P_2O_5).

Varieties—three, R6 Budhiabako (late), R10 Chhatri (fine, scented, medium ripening) and R2 Nungi (early).

The experimental field was located in block V of Labhandi farm, Raipur.

The soil was of a heavy type—*Dorsa* (clay loam)—containing nearly 48 per cent clay, 5 per cent fine silt and 8 per cent silt (Appendix A).

The ultimate size of the plot was 1/40th acre ($17\frac{1}{3}$ ft. × $61\frac{1}{3}$ ft.) with $2\frac{1}{3}$ ft. as non-experimental margin.

Agricultural. The method of cultivation was *biasi.** No basal manuring was given and the fertilizers were applied two weeks after *biasi.* The crop was irrigated and the rotation every year was rice after rice.

TABLE I

Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of paddy Combined results of five years, 1939 to 1943

Soil.—Dorsa (*clay loam*)

Treatments	Average yield five years in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At pre-war prices—August 1939			At rates prevailing in December 1943		
				Value of extra yield	Cost of ferti-lizers	Profit or loss	Value of extra yield	Cost of ferti-lizers	Profit
			R6 Budhiabako (late)						
Per acre	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
0 lb. N + 0 lb. P_2O_5	988	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,197	209	21	4 3	1 15	2 4	13 15	4 6	9 9
0 lb. N + 20 lb. P_2O_5	1,233	245	25	4 14	3 15	0 15	16 5	8 12	7 [illegible]
10 lb. N + 0 lb. P_2O_5	1,372	384	39	7 11	2 15	4 12	25 10	6 2	19 8
10 lb. N + 10 lb. P_2O_5	1,592	604	61	12 1	4 14	7 3	40 4	10 8	29 12
10 lb. N + 20 lb. P_2O_5	1,659	671	68	13 7	6 13	6 10	44 12	14 14	29 14
20 lb. N + 0 lb. P_2O_5	1,501	513	52	10 4	5 13	4 7	34 3	12 4	21 15
20 lb. N + 10 lb. P_2O_5	1,676	688	70	13 12	7 12	6 0	45 14	16 10	29 4
20 lb. N + 20 lb. P_2O_5	2,122	1,134	115	22 11	9 12	12 15	75 10	21 0	54 10
					Cr. diff. Rs. 3-3-9			Cr. diff. Rs. 10-13-0	
			R10 Chhatri (fine, scented, medium ripening)						
0 lb. N + 0 lb. P_2O_5	902	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	982	80	9	1 12	1 15	—0 3	5 11	4 6	1 5
0 lb. N + 20 lb. P_2O_5	1,107	205	23	4 9	3 15	0 10	14 10	8 12	5 14
10 lb. N + 0 lb. P_2O_5	1,124	222	25	4 15	2 15	2 0	15 14	6 2	9 12
10 lb. N + 10 lb. P_2O_5	1,290	388	43	8 10	4 14	3 12	27 11	10 8	17 3
10 lb. N + 20 lb. P_2O_5	1,222	320	36	7 2	6 13	0 5	22 14	14 14	8 0
20 lb. N + 0 lb. P_2O_5	1,279	377	42	8 6	5 13	2 9	26 15	12 4	14 11
20 lb. N + 10 lb. P_2O_5	1,445	543	60	12 1	7 12	4 5	38 13	16 10	22 3
20 lb. N + 20 lb. P_2O_5	1,639	737	82	16 6	9 12	6 10	52 10	21 0	31 10
					Cr. diff. Rs. 3-9-9			Cr. diff. Rs. 11-9-3	
			R2 Nungi (early)						
0 lb. N + 0 lb. P_2O_5	745	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	897	152	20	2 11	1 15	0 12	10 2	4 6	5 12
0 lb. N + 20 lb. P_2O_5	989	244	33	4 6	3 15	0 7	16 4	8 12	7 8
10 lb. N + 0 lb. P_2O_5	947	202	27	3 10	2 15	0 11	13 7	6 2	7 5
10 lb. N + 10 lb. P_2O_5	999	254	34	4 9	4 14	—0 5	16 15	10 8	6 7
10 lb. N + 20 lb. P_2O_5	1,119	374	50	6 11	6 13	—0 2	24 15	14 14	10 1
20 lb. N + 0 lb. P_2O_5	1,165	420	56	7 8	5 13	1 11	28 0	12 4	15 12
20 lb. N + 10 lb. P_2O_5	1,171	426	57	7 10	7 12	—0 2	28 6	16 10	11 12
20 lb. N + 20 lb. P_2O_5	1,441	696	93	12 7	9 12	2 11	46 6	21 0	25 6
					Cr. diff. Rs. 2-14-3			Cr. diff. Rs. 10-13-0	

* *Biasi.*—A method of rice cultivation in which seed is sown broad-cast, followed by ploughing to thin out the seedlings when they are a foot high.

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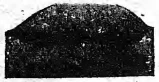
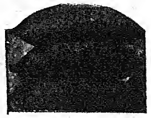
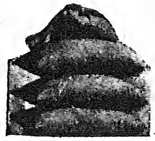
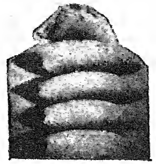
MANURING OF RICE FOR HIGH CROP PRODUCTION

Effect of Fertilizers

Yield of paddy in lb. per acre

[*Average of 5 years, 1939 to 1943*]

988 lb.	1501 lb.	1592 lb.	2122 lb.
			
No manure	Ammonium sulphate 100 lb.* (20 lb. N.)	Ammonium sulphate 50 lb.* + Double super phosphate 25 lb. ** (10 lb. N. +10 lb. P_2O_5)	Ammonium sulphate 100 lb.* + Double super phosphate 50 lb.** (20 lb. N.+20 lb. P_2O_5)

Increase ...	52%	61%	115%
Extra yield ...	513 lb.	604 lb.	1134 lb.
At per-war prices (August 1939)			
Value at 50 lb. a rupee ...	Rs. 10/4	Rs. 12/1	Rs. 22/11
Cost of manure ...	Rs. 5/13*	Rs. 2/15*+1/15**=4/14	Rs. 5/13*+3/15**=9/12
Profit ...	Rs. 4/7	Rs. 7/3	Rs. 12/15
At rates prevailing in December 1943			
Value at 15 lb. a rupee ...	Rs. 34/3	Rs. 40/4	Rs. 75/10
Cost of manure ...	Rs. 12/4*	Rs, 6/2*+4/6**=10/8	Rs. 12/4*+8/12**=21/—
Profit ...	Rs. 21/15	Rs. 29/12	Rs. 54/10

[Rice Research Scheme, C. P.]

S.E. of Tr. mean	'Z' test	Cr. diff. P = 0·05	*Conclusions.—R6 Budhiabako (late)*
			20 N > 20N 10N 10N 20N 10N 20P 10P > No manure 20P 10P 20P 10P
58·55	Varieties.—Significant at 1 per cent	162·16	*R 10 Chhatri*
	Nitrogen.—Significant at 1 per cent		
	Phosphoric acid.—Significant at 1 per cent		20 N > 20 N 10 N 20 N 10 N 10 N 20 P 10 P No manure
	V × N.—Significant at 1 per cent		20 P 10 P 10 P 20 P
	N × P.—Significant at 1 per cent		
	V × P.—Insignificant		*R2 Nungi (early)*
	V × N × P.—Insignificant		20 N > 20 N 20 N 10 N 10 N 20 P 10 N 10 P No manure 20 P 10 P 20 P 10 P

Pre-war prices, August 1939.—Ammonium sulphate at Rs. 6-8-6 per cwt. Double superphosphate at Rs. 8-12-0 per cwt. Budhiabako paddy at 50 lb. Chhatri at 45 lb. and Nungi at 56 lb. a rupee.

Rates prevailing in December 1943.—Ammonium sulphate at Rs. 13-12-0 per cwt Double superphosphate at Rs. 19-9-6 cwt. Bhudhiabako paddy at 15 lb. Chhatri at 14 lb. and Nungi at 15 lb. a rupee.

The results show that on heavier soils (*Dorsa*, clay loam) the highest yield and largest net profit are obtained only when nitrogenous and phosphatic fertilizers are given in combination. The most effective nitrogen and phosphate ratio is 1 : 1. The application of 20 lb. nitrogen in the form of ammonium sulphate with 20 lb. phosphoric acid in the form of double superphosphate per acre has given significantly higher yield than either 20 lb. nitrogen or 20 lb. phosphoric acid applied alone. Individually, 20 lb. nitrogen is significantly better than 20 lb. phosphoric acid, and 20 lb. phosphoric acid significantly better than no manure.

The application of 20 lb. nitrogen with 20 lb. phosphoric acid (100 lb. ammonium sulphate with 50 lb. double superphosphate) per acre increased the yield of late paddy R6 Budhiabako from 988 lb. to 2,122 lb., an increase of 115 per cent; of fine scented variety R10 Chhatri from 902 lb. to 1,639 lb., an increase of 82 per cent; and of early paddy R2 Nungi from 745 lb. to 1,441 lb., an increase of 93 per cent.

The effect of main treatments on the yield of late paddy R6 Budhiabako commonly grown on these soils, and net profits per acre were as follows:
(Plate XVI).

Treatments	Increase over no manure, lb.	Percentage of increase over no manure	Profit: At pre-war rates—August 1939	Profit: At rates prevailing in December 1943
(Per acre)	Per acre		Rs. a.	Rs. a.
100 lb. ammonium sulphate + 50 lb. double superphosphate	1,134	115	12 15	54 10
50 lb. ammonium sulphate + 25 lb. double superphosphate	604	61	7 3	29 12
100 lb. ammonium sulphate	513	52	4 7	21 15
50 lb. double superphosphate	245	25	0 15	7 9

Experiment 1 (b).—Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of transplanted and 'biasi' rice. Soil.—Light, Matasi (sandy loam).

The experiment was laid out in a 2^4 factorial design with four replications. Each block was split into two sub-blocks of eight plots each and 1 D. F. of the four-factor interaction was confounded with block differences.

The treatments were—

Nitrogen at two levels—0 and 10 lb. per acre, in the form of ammonium sulphate.

Phosphoric acid at two levels—0 and 10 lb. per acre, in the form of double superphosphate.

Methods of cultivation—Two, transplantation and *biasi*.

Varieties—Two, R6 Budhiabako (late) and R2 Nungi (early).

The experimental field was located in block VI of Labhandi farm.

The soil was *Ma'asi* (sandy loam), of average fertility, containing nearly 25 per cent clay, 4 per cent fine silt and 9 per cent silt. (Appendix A).

The ultimate size of the plot was 1/40th acre ($17\frac{1}{3}$ ft. $\times$ $61\frac{1}{3}$ ft.) with $2\frac{1}{3}$ ft. as n n-experimental margin.

No basal manuring was given and fertilizers were applied at the time of transplantation and two weeks after *biasi*. The crop was irrigated and the rotation was rice after rice.

TABLE II.

Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of transplanted and 'biasi' rice

Combined results of five years, 1939 to 1943

Soil—Matasi (*sandy loam*)

Treatments	Average yield (five years) in lb.	Increase over no manure, in lb.	At pre-war prices—August 1939: Percentage of increase over no manure	At pre-war prices—August 1939: Value of extra yield	At pre-war prices—August 1939: Cost of fetrilizers	At pre-war prices—August 1939: Profit or loss	At rates prevailing in December 1943: Value of extra yield	At rates prevailing in December 1943: Cost of fertilizers	At rates prevailing in December 1943: Profit
			Transplanted						
			R6 Budhiabako (late)						
(Per acre)	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
0 lb. N + 0 lb. P_2O_5	1,158	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,355	197	17	3 15	1 15	2 0	13 2	4 6	8 12
10 lb. N + 0 lb. P_2O_5	1,519	361	31	7 4	2 15	4 5	24 1	6 2	17 15
10 lb. N + 10 lb. P_2O_5	1,851	693	60	13 14	4 14	9 0	46 3	10 8	35 11
					Cr. Diff. Rs. 2-6-6			Cr. Diff. Rs. 8-0-9	
			R2 Nungi (early)						
0 lb. N + 0 lb. P_2O_5	914	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,095	181	20	3 4	1 15	1 5	12 1	4 6	7 11
10 lb. N + 0 lb. P_2O_5	1,279	365	40	6 8	2 15	3 9	24 5	6 2	18 3
10 lb. N + 10 lb. P_2O_5	1,487	573	63	10 4	4 14	5 6	38 3	10 8	27 11
					Cr. Diff. Rs. 2-2-6			Cr. Diff. Rs. 8-0-9	
			Biasi						
			R6 Budhiabako (late)						
0 lb. N + 0 lb. P_2O_5	1,115	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5	1,252	137	12	2 12	1 15	0 13	9 2	4 6	4 12
10 lb. N + 0 lb. P_2O_5	1,309	191	17	3 14	2 15	0 15	12 15	6 2	6 13
10 lb. N + 10 lb. P_2O_5	1,491	376	34	7 8	4 14	2 10	25 1	10 8	14 9
					Cr. Diff. Rs. 2-6-6			Cr. Diff. Rs. 8-0-9	

TABLE II—*contd.*

Effect of nitrogenous and phosphatic fertilzers applied alone and in combination on the yield of transplanted and 'biasi' rice—contd.

Combined results of five years, 1932 to 1943—contd.

Treatment	Average yeild (five years) in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At pre-war prices—August 1939.			At rates prevailing in December 1943		
				value of extra yeild	Cost of ferti-lizers	Profit or loss	value of extra yeild	Cost of ferti-lisers	Profit
			R2 Nungi (early)						
0 lb. N + 0 lb. P_2O_5 . . .	738	..	..	..	..	..	..	..	..
0 lb. N + 10 lb. P_2O_5 . . .	842	104	14	1 14	1 15	—0 1	6 15	4 6	2 9
10 lb. N + 0 lb. P_2O_5 . . .	958	220	30	3 15	2 15	1 0	14 11	6 2	8 9
10 lb. N + 10 lb. P_2O_5 . . .	1,113	375	51	6 11	4 14	1 13	25 0	10 8	14 8
						Cr. Diff. Rs. 2-2-6			Cr. Diff. Rs. 0-8-9

S. E. of Tr. mean 43·58 — 'Z' test — Cr. Diff. P = 0·05 120·8

Nitrogen.—Significant at 1 per cent.

Phosphoric acid.—Significant at 1 per cent.

Cultivation methods.—Significant at 1 per cent.

Varieties.—Significant at 1 per cent.

N × C.—Significant at 1 per cent.

V × C.—Significant at 5 per cent.

Remaining interactions.—Insignificant

Conclusions —

Transplanted.

R6 Budhiabako

10 lb. N, 10 lb. P > 10 lb. N > 10 lb. P > No manure

R2 Nungi

10 lb. N, 10 lb. P > 10 lb. N > 10 lb. P > No manure

Biasi

R6 Budhiabako

10 lb. N, 10 lb. P > 10 lb. N 10 lb. P > No manure

R2 Nungi

10 lb. N, 10 lb. P > 10 lb. N 10 lb. P No manure

The results show that on light soils (*Matasi*, sandy loam) the combination of nitrogenous and phosphatic fertilizers has given the highest yield and the largest net profit. The application of 10 lb. nitrogen in the form of ammonium sulphate with 10 lb. phosphoric acid in the form of double superphosphate per acre has given significantly higher yield than either 10 lb. nitrogen or 10 lb. phosphoric acid applied alone. With transplanted rice, 10 lb. nitrogen per acre is significantly better than 10 lb. phosphoric acid, and 10 lb. phosphoric acid significantly better than no manure.

The application of 10 lb. nitrogen with 10 lb. phosphoric acid (50 lb. ammonium sulphate with 25 lb. double superphosphate) per acre increased the yield of late paddy R6 Budhiabako from 1,158 lb. to 1,851 lb., an increase of 60 per cent and of early paddy R2 Nungi from 914 lb. to

1,487 lb., an increase of 63 per cent, when both were transplanted. The net profits per acre (compared with the application of ammonium sulphate alone) were as follows :

Treatments	Increase over no manure lb.	Percentage of increase over no manure	Profit: At pre-war rates—August 1939	Profit: At rates prevailing in December 1943
(Per acre)			Rs. a.	Rs. a.
	R6 Budhiabako (late)			
50 lb. Ammonium sulphate+25 lb. double superphosphate	693	60	9 0	35 11
50 lb. Ammonium sulphate	361	31	4 5	17 15
	R2 Nungi (early)			
50 lb. ammonium sulphate+25 lb. double superphosphate .	573	63	5 6	27 11
50 lb. Ammonium sulphate	365	40	3 9	18 3

TABLE III.

Effect of nitrogenous and phosphatic fertilizers applied alone and in different combinations Combined results of three years, 1935 to 1937

Soil.—Very light, shallow Matasi *(sandy loam) 9 inches deep*

Treatments	Average yield (five years) lb.	Increase over no manure lb.	Percentage of increase over no manure	At pre-war prices—August 1939: Value of extra yield	At pre-war prices—August 1939: Cost of ferti-lizers	At pre-war prices—August 1939: Profit or loss	At rates prevailing in December 1943: Value of extra yield	At rates prevailing in December 1943: Cost of ferti-lizers	At rates prevailing in December 1943: Profit or loss
(Per acre)	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
0 lb. N+ 0 lb. P_2O_5 . . .	879	..	..	..	..	..	..	..	..
0 lb. N+20 lb. P_2O_5 . . .	1,326	447	51	8 0	3 14	4 2	29 13	8 12	21 1
0 lb. N+30 lb. P_2O_5 . . .	1,333	454	52	8 2	5 13	2 5	30 4	13 2	17 2
0 lb. N+40 lb. P_2O_5 . . .	1,388	509	58	9 1	7 12	1 5	33 15	17 8	16 7
20 lb. N+ 0 lb. P_2O_5 . . .	903	24	3	0 7	5 14	—5 7	1 10	12 4	—10 10
20 lb. N+20 lb. P_2O_5 . . .	1,582	703	80	12 9	9 12	2 13	46 14	21 0	25 14
20 lb. N+30 lb. P_2O_5 . . .	1,637	758	86	13 9	11 11	1 14	50 9	25 6	25 3
20 lb. N+40 lb. P_2O_5 . . .	1,661	782	89	13 15	13 10	0 5	52 2	29 12	22 6
30 lb. N+ 0 lb. P_2O_5 . . .	920	41	5	0 12	8 13	8 1	2 12	18 6	—15 10
30 lb. N+20 lb. P_2O_5 . . .	1,617	738	84	13 3	12 11	0 8	49 3	27 2	22 1
30 lb. N+30 lb. P_2O_5 . . .	1,799	920	105	16 7	14 10	1 13	61 5	31 8	29 13
30 lb. N+40 lb. P_2O_5 . . .	1,761	882	100	15 12	16 9	—0 13	58 13	35 14	22 15
40 lb. N+ 0 lb. P_2O_5 . . .	934	55	6	1 0	11 12	—10 12	3 11	24 8	—20 13
40 lb. N+20 lb. P_2O_5 . . .	1,778	899	102	16 1	15 10	0 7	59 15	33 4	26 11
40 lb. N+30 lb. P_2O_5 . .	1,818	939	107	16 12	17 9	—0 13	62 10	37 10	250
40 lb. N +40 lb. P_2O_5 . .	2,011	1,132	129	20 3	19 8	0 11	75 7	42 0	337
					Cr. Diff.	Rs. 4-7-6		Cr. Diff.	Rs. 16-11-6

S. E. of Tr. mean=90·5. ‘Z’ test (P=0·01)—Significant. Cr. Diff. (P=0·05)=250·8

Conclusions—

40 N	40 N	30 N	40 N	30 N	20 N	20 N	30 N	20 N	40 N	30 N	20 N	No manure.
40 P	30 P	30 P	20 P	40 P	40 P	30 P	20 P	20 P	40 P	30 P	20 P	

In *biasi* rice the application of 50 lb. ammonium sulphate, with 25 lb. double superphosphate per acre increased the yield of R6 Budhiabako from 1,115 lb. to 1,491 lb., an increase of 34 per cent, and of R2 Nungi from 738 lb. to 1,113 lb., an increase of 51 per cent. On light soils, with *biasi* system of cultivation, the effect of fertilizers was not so pronounced as under transplantation, indicating that the time of application of fertilizers may be an important factor which needs investigation. Transplanted rice gave significantly higher yield than *biasi* rice.

Experiment 1 (c).—Effect of nitrogenous and phosphatic fertilizers applied alone and in different combinations on the yield of paddy. Soil—Very light and shallow Matasi (sandy loam), 9 inches deep.

The experiment was laid out in randomized blocks with six replications, each replicate having 16 treatment combinations. The treatments were—

Nitrogen at four levels—0, 20, 30 and 40 lb. per acre in the form of ammonium sulphate (20 per cent N).

Phosphoric acid at four levels—0, 20, 30 and 40 lb. per acre in the form of double superphosphate (40 per cent P_2O_5).

The experimental field was located at Chandkhuri farm, Raipur, and the soil was very light, shallow *Matasi* (sandy loam), 9 inches deep. The ultimate size of the plot was 1/50th acre ($13\frac{3}{4}$ ft. $\times$ $63\frac{1}{4}$ ft.) with $1\frac{1}{3}$ ft. as non-experimental margin. The variety was R4 Surmatia (medium in ripening) and the method of cultivation was *biasi*. No basal manuring was given and the fertilizers were applied at the time of *biasi*. The crop was irrigated and rotation was rice after rice.

The results show that on very light, shallow, laterite soils phosphoric acid is the limiting factor. The application of 20 lb. P_2O_5 (50 lb. double superphosphate) per acre increased the yield of paddy from 879 lb. to 1,326 lb., an increase of 51 per cent, and gave the largest net profit, at pre-war rates. Differences in yields due to the application of 20, 30 or 40 lb. phosphoric acid per acre were, however, not significant.

Very light and shallow laterite soils do not respond to the application of nitrogen even to the extent of 40 lb. per acre. The application of nitrogenous fertilizers alone is, therefore, accompanied with loss.

A combination of nitrogenous and phosphatic fertilizers is very effective in bringing about significant increase in yield over phosphates applied alone or over no manure. The most effective nitrogen and phosphate ratio is 1 : 1. The application of 20 lb. nitrogen with 20 lb. phosphoric acid (100 lb. ammonium sulphate with 50 lb. double superphosphate) per acre increased the yield of paddy from 879 lb. to 1,582 lb., an increase of 80 per cent ; 30 lb. N+30 lb. P_2O_5 increased the yield from 879 lb. to 1,799 lb., an increase of 105 per cent, and 40 lb. N+40 lb. P_2O_5 increased the yield from 879 lb. to 2,011 lb., an increase of 129 per cent.

Simplified experiments to test the results obtained at the Rice Research Station were laid out, in randomized blocks with five replications, on the cultivators' holdings in 23 important *tahsils* of the rice growing tracts. The results of some of these are summarized below.

The results confirm that highest yield and largest net profit are obtained only when nitrogenous and phosphatic fertilizers are given in combination. The application of 100 lb. ammonium sulphate with either 50 lb. or 25 lb. double superphosphate per acre is profitable and increases the yield, on an average, by 100 and 70 per cent, respectively. If the cultivators are not able to use this quantity of fertilizers (costing Rs. 9-12-0 and Rs. 7-12-0, respectively, at pre-war prices), a dressing of at least 50 lb. ammonium sulphate with 25 lb. double superphosphate per acre (costing Rs. 4-14-0) is recommended. This application of fertilizers will increase the yield, on an average, by 50 per cent and will be definitely profitable.

Experiment 2.—Effect of organic and inorganic manures and their mixtures on the yield of paddy.

The experiment was laid out in randomized blocks with five replications. The treatments were—

(1) No manure.
(2) Inorganic nitrogen, 10 lb. per acre (Ammonium sulphate 50 lb.).
(3) Inorganic nitrogen, 20 lb. per acre (Ammonium sulphate 100 lb.).
(4) Organic nitrogen, 10 lb. per acre (Farmyard manure. Nitrogen in air dry sample 0 8 per cent.)

TABLE IV.

Effect of nitrogenous and phosphatic fertilizers applied alone and in combination on the yield of paddy

Treatments	Piprod village, Raipur *tahsil* Soil.—*Matasi* (sandy loam) Average, 1940 and 1941				Kosmandi village, Balodabazar Soil.—*Matasi* 1941				Karhidih village, Mahasamund Soil.—*Matasi* 1941			
	Mean yield per acre	Increase over no manure	Per cent increase over no manure	Profit or loss*	Mean yield per acre	Increase over no manure	Percent increase over no manure	Profit or loss*	Mean yield per acre	Increase over no manure	Per cent increase over no manure	Profit or loss*
					Variety.—R6 Budhiabako (late)							
(Per acre)	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.
0 lb. N+ 0 lb. P_2O_5	588	..	..	..	568	..	..	..	1,324	..	..	..
0 lb. N+10 lb. P_2O_5	800	212	36	2 5	760	192	34	1 14	1,380	56	4	−0 13
10 lb. N+ 0 lb. P_2O_5	680	92	16	−1 1	552	−16	−3	−3 3	1,716	392	30	4 15
10 lb. N+10 lb. P_2O_5	920	332	56	1 13	912	344	61	2 1	1,732	408	31	3 6
20 lb. N+ 0 lb. P_2O_5	628	40	7	−5 0	592	24	4	−5 5	1,822	498	28	4 2
20 lb. N+10 lb. P_2O_5	1,020	432	73	0 14	1,064	496	87	2 3	1,922	598	45	4 3
20 lb. N+20 lb. P_2O_5	1,552	964	164	9 9	1,312	744	131	5 3	2,000	676	51	3 12

	S. E. of Tr. mean	'Z' test	Cr. diff.	S. E. of Tr. mean	'Z' test	Cr. diff.	S. E. of Tr. mean	'Z' test	Cr. diff.
		P=0·01	P=0·05		P=0·05	P=0·05		P=0·01	P=0·05
	109·6	Significant	320·0	65·8	Significant	192·1	101·8	Significant	297·0

Conclusions —

20N 20N 10N 10N 20N No 20N 20N 10N 20N No 10N 20N 20N 20N 10N 10N No
20P 10P 10P 10P M. 20P 10P 10P 10P M. 20P 10P 10P 10P M

Treatments	Ganeshpur village, Waraseoni Soil.—Sihar (sandy loam), light				Richhai farm, Jubbulpore Sandy soil, *Sehra*							
	1939				1938				1939			
	Variety.— R10 Chhatri				*Variety.—R13 Chhatri*				*Variety.—R6 Budhiabako*			
(Per acre)	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.	Lb.	Lb.		Rs. a.
0 lb. N+ 0 lb. P_2O_5	568	..	..	..	1,197	..	..	..	526	..	..	..
0 lb. N+10 lb. P_2O_5	701	133	23	1 0	1,455	258	22	3 13	761	235	45	2 12
0 lb. N+20 lb. P_2O_5	897	329	57	3 7	1,362	165	14	−0 3	706	180	34	−0 4
10 lb. N+ 0 lb. P_2O_5	686	118	21	−0 4	1,377	180	15	1 2	898	372	71	4 9
10 lb. N+10 lb. P_2O_5	975	407	72	4 4	1,695	498	42	6 4	978	452	83	4 4
10 lb. N+20 lb. P_2O_5	933	365	64	1 6	1,533	336	28	0 11	834	308	59	−0 9
20 lb. N+ 0 lb. P_2O_5	941	373	66	2 8	1,326	129	11	−2 15	1,074	548	62	5 2
20 lb. N+10 lb. P_2O_5	1,124	556	98	4 10	1,755	558	47	4 10	809	283	54	−2 1
20 lb. N+20 lb. P_2O_5	938	370	65	−1 7	1,659	462	39	0 9	1,181	655	125	3 7

	S. E. of Tr. mean	'Z' test	Cr. diff.	S. E. of Tr. mean	'Z' test	Cr. diff.	S. E. of Tr. mean	'Z' test	Cr. diff.
		P=0·01	P=0·05		P=0·05	P=0·05		P=0·01	P=0·05
	98·5	Significant	273·3	114·5	Significant	330·9	122·2	Significant	338·8

Conclusions —

20N 10N 20N 20N 10N 20P 10P 10N No 20N 10N 20N 10N 10P 10N 20P 20N No 20N 20N 10N 10N 10N 20N 10P 20P No
10P 10P 20P 20P M. 10P 10P 20P 20P M. 20P 10P 20P 10P M.

* At pre-war prices.

(5) Organic nitrogen, 20 lb. per acre.
(6) Inorganic nitrogen 5 lb. + Organic nitrogen 5 lb. per acre.
(7) Inorganic nitrogen 10 lb. + Organic nitrogen 10 lb. per acre.

The experimental field was *rabi* land diverted to paddy, in block V of Labhandi farm and the soil was heavy *Dorsa* (clay loam). The ultimate size of the plot was 1/50th acre ($13\frac{3}{4}$ft.$\times 63\frac{1}{4}$ft.) with $1\frac{1}{3}$ ft. as non-experimental margin. The variety was R6 Budhiabako (late) and the method of cultivation was *biasi*. Farmyard manure was applied before the sowing of seed in June and fertilizers were applied two weeks after *biasi*. The crop was irrigated and the rotation every year was rice after rice.

TABLE V

Effect of organic and inorganic manures and their mixtures on the yield of paddy
Combined results of five years, 1939 to 1943
Soil.—Heavy Dorsa *(clay loam).* Rabi *land diverted to paddy*

Treatments	Average yield (five years) in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At pre-war prices, August 1939			At rates prevailing in December 1943		
				Value of extra yield	Cost of manure	Profit	Value of extra yield	Cost of manure	Profit
(Per acre)	Per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
No manure	648	..	..	..	..	..	..	..	..
Farmyard manure 10 lb. N	875	227	35	4 9	1 9	3 0	15 2	3 2	12 0
Farmyard manure 20 lb. N	1,017	369	57	7 6	3 2	4 4	24 10	6 4	18 6
Farmyard manure 5 lb. N + Ammonium sulphate 5 lb. N	1,060	412	64	8 4	2 4	6 0	27 7	4 10	22 13
Farmyard manure 10 lb. N + Ammonium sulphate 10 lb. N.	1,215	567	87	11 5	4 8	6 13	37 13	9 4	28 9
Ammonium sulphate 10 lb. N	1,076	428	66	8 9	2 15	5 10	28 9	6 2	22 7
Ammonium sulphate 20 lb. N	1,323	675	104	13 8	5 13	7 11 Cr. Diff. Rs. 2-13-0	45 0	12 4	32 12 Cr. Diff. Rs. 9-6-3

S. E. of Tr. mean =48·28 'Z' test (P=0·01) Significant Cr. Diff. (P=0·05)=140·9

Conclusions—
NH_4SO_4—20 lb. N NH_4SO_4—10 lb. N F.Y.M. 10 lb. N NH_4SO_4—10 lb. N. NH_4SO_4—5 lb. N F.Y.M. 5 lb. N F.Y.M.—20 lb. N > F.Y.M.—10 lb. N > No manure

Pre-war prices, August 1939.—Farmyard manure at Re. 1 per cart of 800 lb. Nitrogen in air dry sample =0·8 per cent.
Rates prevailing in December 1943.—Farmyard manure at Rs. 2 per cart of 800 lb.

The results show that on heavy soils (*Dorsa*, clay loam) nitrogenous fertilizers alone, or a mixture of organic and inorganic nitrogen gives significantly higher yield than farmyard manure applied on the same nitrogen basis. The average yield per acre of plots receiving 100 lb. ammonium sulphate (20 lb. N.) was 1,323 lb. and of those supplied with a mixture of 10 lb. nitrogen as farmyard manure with 10 lb. nitrogen as ammonium sulphate, 1,215 lb., against 1,017 lb. of plots receiving 20 lb. nitrogen as farmyard manure.

20 lb. nitrogen per acre applied as farmyard manure gave the same yield as 10 lb. nitrogen supplied as ammonium sulphate, or a mixture of 5 lb. organic and 5 lb. inorganic nitrogen.

The need for a dressing of nitrogenous fertilizers is clearly indicated.

Experiment 3.—Effect of different quantities of nitrogen applied in the form of compost on the yield of paddy

The experiment was laid out in randomized blocks with six replications on two different soils at Labhandi farm, Raipur. The treatments were 0, 20, 40 and 60 lb. nitrogen per acre in the form of compost (nitrogen in air dry sample—0·5 per cent). The ultimate size of the plot was 1/80th acre ($18\frac{1}{2}$ ft. × $29\frac{1}{2}$ ft.) with $1\frac{3}{4}$ ft. as non-experimental margin. The method of cultivation was *biasi* and compost was applied before the sowing of seed. The variety was R6 Budhiabako (late) and the crop was irrigated. Rotation every year was rice after rice.

TABLE VI

Effect of different quantities of nitrogen applied in the form of compost on the yield of paddy Combined results of three years, 1942 to 1944

Treatments	Average yield (three yrs.) in lb.	Increase over no manure in lb.	At pre-war prices, August 1939				At rates prevailing in December 1943		
			Percentage of increase over no manure	Value of extra yield	Cost of manure	Profit	Value of extra yield	Cost of manure	Profit
(Per acre)	per acre			Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
			Soil.—Matasi (sandy loam)						
No manure	921	..	..	..	..	..	..	..	..
Compost 20 lb. N	1,173	252	27	5 1	2 8	2 9	16 13	5 0	11 13
Compost 40 lb. N	1,352	431	47	8 10	5 0	3 10	28 12	10 0	18 12
Compost 60 lb. N	1,549	628	68	12 9	7 8	5 1 Cr. Diff. Rs. 2-1-0	41 14	15 0	26 11 Cr. Diff. Rs. 6-14-3

S.E. of tr. mean=34·32 'Z' test.—Significant at 1 per cent Cr. Diff. (P=0·05)=103·36

Conclusions.—N 60 > N 40 > N 20 > No manure

Soil.—Dorsa (clay loam)

Treatments	Average yield	Increase over no manure	Percentage of increase	Value of extra yield	Cost of manure	Profit	Value of extra yield	Cost of manure	Profit
No manure	968	..	..	..	..	..	..	..	..
Compost 20 lb. N	1,129	161	17	3 4	2 8	0 12	10 12	5 0	5 12
Compost 40 lb. N	1,383	415	43	8 5	5 0	3 5	27 11	10 0	17 11
Compost 60 lb N	1,550	582	60	11 10	7 8	4 2 Cr. Diff. Rs. 2-15-0	38 13	15 0	23 13 Cr. Diff. Rs. 9-12-6

S. E. of tr. mean=48·72 'Z' test.—Significant at 1 per cent Cr. Diff. (P=0·05)=146·84

Conclusions.—N 60 > N 40 > N 20 > No manure

of Pre-war prices, August 1939.—Compost made of vegetable waste matter with a small amount of cowdung as a 'starter' at as. 8 per cart 80 lb. (Nitrogen in air dry sample=0·5 per cent)
Rates prevailing in December 1943.—Compost at Re. 1 per cart

On light soil (*Matasi*) the application of 60 lb. nitrogen in the form of compost increased the yield of paddy from 921 lb. to 1,549 lb. per acre, an increase of 68 per cent; 40 lb. nitrogen increased the yield to 1,352 lb., an increase of 47 per cent and 20 lb. nitrogen increased it to 1,173 lb., an increase of 27 per cent. The net profits were all statistically significant.

Similar results were obtained on heavy soil (*Dorsa*), but the effect of 20 lb. nitrogen in the form of compost was less pronounced.

Experiment 4.—Effect of different quantities of nitrogen applied in the form of oil-cakes on the yield of paddy

The experiment comprising a study of the effects of groundnut, linseed and sesamum (*til*) cakes, each applied at 0, 20, 40 and 60 lb. nitrogen per acre on the yield of paddy was laid out in six randomized blocks, each having 12 plots. There were three unmanured plots in each block thus giving only 10 different treatments. The soils were sandy loam (*Matasi*) and clay loam (*Dorsa*) at Labhandi farm, Raipur. The ultimate size of the plot was 1/80th acre ($18\frac{1}{2}$ ft. × $29\frac{1}{2}$ ft.) with $1\frac{3}{4}$ ft. as non-experimental margin. The method of cultivation was *biasi* and oil-cakes were applied at the time of sowing of seed. The variety was R6 Budhiabako (late) and the crop was irrigated. Rotation every year was rice after rice.

TABLE VII

Effect of different quantities of nitrogen applied in the form of oilcakes on the yield of paddy
Combined results of three years, 1942 to 1944

Treatments	Average yield (3 years) in lb.	Increase over no manure in lb.	At rates prevailing in December 1943*: Percentage of increase over no manure	Value of extra yield	Cost of manure	Profit or loss
(Per acre)	per acre			Rs. a.	Rs. a.	Rs. a.
			Soil.—Matasi (*sandy loam*)			
No manure	1,079	..	..	..	..	..
Groundnut cake—						
20 lb. N.	1,342	263	24	17 9	14 0	3 9
40 lb. N.	1,714	635	59	42 5	28 0	14 5
60 lb. N.	2,030	951	88	63 6	42 0	21 6
Linseed cake—						
20 lb. N.	1,410	331	31	22 1	25 12	—3 11
40 lb. N.	1,685	606	56	40 6	51 8	—11 2
60 lb. N.	2,076	997	92	66 7	77 4	—10 13
Til cake—						
20 lb. N.	1,382	303	28	20 3	17 12	2 7
40 lb. N.	1,821	742	69	49 7	35 8	15 15
60 lb. N.	1,120	1,041	96	69 6	53 4	16 2
		Cr. diff.	(P=0·05) 157·9	Cr. diff. Rs. 10-8-6		

S. E. of tr. mean 56·96

'Z' test

Quality of nitrogen—Significant at 5 per cent
Quantity of nitrogen—Significant at 1 per cent
Interactions—
Quality × Quantity.—Insignificant
Quality × Season—Insignificant
Quantity × Season—Insignificant
Treatments.—Significant at 1 per cent

* Rates prevailing in December 1943.—Groundnut cake (7 per cent nitrogen) at Rs. 4 per maund. Linseed cake at (4·5 per cent N.) at Rs. 4-12-0 per maund. *Til* cake (5·2 per cent N.) at Rs. 3-12-6 per maund. Buddhiabako paddy 15 lb. per rupee

Quality of nitrogen

Mean yield of all the plots receiving groundnut cake—1,695 lb. per acre
Mean yield of all the plots receiving linseed cake—1,724 lb. per acre
Mean yield of all the plots receiving *til* cake—1,812 lb. per acre
Cr. diff. = 91·15 lb. per acre

Conclusions—Til cake Linseed cake Groundnut cake

Quantity of nitrogen and *treatments*:
Conclusions (in order of yield):

T. N. 60, L.N. 60, G. N. 60>T.N. 40, G.N. 40, L.N. 40>L.N. 20, T.N. 20, G. N. 20>No manure

Treatments	Average yield (3 years) in lb.	Increase over no manure in lb.	Percentage of increase over no manure	At rates prevailing in December 1943: Value of extra yield	Cost of manure	Profit or loss
(Per acre)	per acre			Rs. a.	Rs. a.	Rs. a.
			Soil.—Dorsa (clay loam)			
No manure	1,067	..	..	..	..	..
Groundnut cake—						
20 lb. N.	1,361	294	28	19 10	14 0	5 10
40 lb. N.	1,693	626	59	41 12	28 0	13 12
60 lb. N.	2,015	948	89	63 3	42 0	21 3
Linseed cake—						
20 lb. N.	1,615	548	51	36 9	25 12	10 13
40 lb. N.	1,893	826	77	55 1	51 8	3 9
60 lb. N.	2,138	1,071	100	71 6	77 4	—5 14
Til cake—						
20 lb. N.	1,327	260	24	17 5	17 12	—0 7
40 lb. N.	1,839	772	72	51 7	35 8	15 15
60 lb. N.	2,187	1,120	105	74 11	53 4	21 7
			Cr. diff. (P=0·05) 146·6			Cr. diff. Rs. 11-4-3

S. E. of tr. mean 60·98

'Z' test

Quality of nitrogen—Significant at 1 per cent
Quanity of nitrogen—Significant at 1 per cent
Seasons—Significant at 1 per cent
Interactions—
Quality × Quantity—Insignificant
Season × Quality—Significant at 1 per cent
Season × Quantity—Significant at 5 per cent
Treatments—Significant at 1 per cent

Quality of nitrogen

Mean yield of all the plots receiving groundnut cake—1,689 lb. per acre
Mean yield of all the plots receiving linseed cake—1,882 lb. per acre
Mean yield of all the plots receiving *til* cake—1,784 lb. per acre.
Cr. diff. = 84·58 lb. per acre

Conclusions.—Linseed cake > *Til* cake > Groundnut cake

Quanity of nitrogen

Mean yield of 60 lb. nitrogen in all the plots receiving groundnut, linseed and *til* cake=2,113 lb. per acre
Mean yield of 40 lb. nitrogen in all the plots receiving groundnut, linseed, and *til* cake=1,808 lb. per acre
Mean yield of 20 lb. nitrogen in all the plots receiving groundnut, linseed and *til* cake=1,434 lb. per acre
Mean yield of 0 lb. nitrogen in all the plots receiving groundnut, linseed and *til* cake (No. manure)=1,067 lb. per acre
Cr. diff. = 84·58 lb. per acre

Conclusions—60 lb. N > 40 lb. N > 20 lb. N > No manure

Seasons

Mean yield of all the plots during 1942=1,402 lb. per acre
Mean yield of all the plots during 1943=1,515 lb. per acre
Mean yield of all the plots during 1944=1,899 lb. per acre
Cr. diff. = 73·3 lb. per acre

Conclusions—1944 > 1943 > 1942

Season × quality of nitrogen

Differences in yeilds in lb. per acre

Oil-cakes	Season		
	1942	1943	1944
Linseed minus *til* cake	—29	175	148
Linseed minus groundnut	168	358	50
Til minus groundnut cake	197	183	—98

Cr. diff.=146·6

In 1942 season, the application of *til* or linseed cake has given significantly higher yield than groundnut cake; the difference between *til* and linseed cake being insignificant.

In 1943, linseed cake is significantly better than *til* cake and *til* cake significantly better than groundnut cake.

In 1944, again, linseed cake is significantly better than *til* cake, but the differences between linseed and groundnut cake or groundnut and *til* cake are not significant.

In the combined results of all the three years, linseed cake is significantly better than *til* cake and *til* cake significantly better than groundnut cake.

Season × quantity of nitrogen

Differences in yields in lb. per acre

Season	Quantity of nitrogen			
	60 lb. N	40 lb. N	20 lb. N	0 lb. N
1944 minus 1943	372	359	434	369
1943 minus 1942	177	200	2	77
1944 minus 1942	549	559	436	446

Cr. diff.=146·6.

Differences in yields between no manure plots of 1942 and 1943, and also between plots receiving 20 lb. nitrogen in the same two years are not statistically significant.

With higher dose of nitrogen difference in yield between one season and the other is significant.

TREATMENTS

Conclusions.—(In order of yield)

T. N. 60, L. N. 60, G. N. 60, L. N. 40 T. N. 40, G. N. 40, L. N. 20.>G. N. 20, T. N. 20> No Manure

At pre-war prices it was not profitable to manure paddy with the above oil-cakes

On light soil (*Matasi*) the application of 60 lb. nitrogen in the form of groundnut cake (10½ maunds) increased the yield of paddy from 1,079 lb. to 2,030 lb. per acre, an increase of 88 per cent and gave a net profit of Rs. 21-6-0 at the present prices. 40 lb. nitrogen in the form of groundnut cake (7 maunds) increased the yield to 1,714 lb. per acre (59 per cent) and gave a net profit of Rs. 14-5-0.

Til cake sufficient to supply 60 lb. nitrogen (14 maunds) increased the yield of paddy from 1,079 lb. to 2,120 lb. per acre (96 per cent) and gave a net profit of Rs. 16-2-0. 40 lb. nitrogen in the form of *til* cake (9 maunds) increased the yield to 1,821 lb. per acre (69 per cent) and gave a net profit of Rs. 13-15-0.

On account of high price and low nitrogen content of linseed cake it was not profitable to apply it.

On heavy soil (*Dorsa*) the application of 60 lb. nitrogen in the form of *til* cake increased the yield of paddy from 1,067 lb. to 2,187 lb. per acre, an increase of 105 per cent and gave a net profit of

Rs. 21-7-0. 40 lb. nitrogen in the form of *til* cake increased the yield to 1,839 lb. per acre (72 per cent) and gave a net profit of Rs. 15-15-0.

A dressing of 60 lb. nitrogen in the form of groundnut cake increased the yield of paddy from 1,067 lb. to 2,015 lb. per acre (89 per cent) and gave a net profit of Rs. 21-3-0. 40 nitrogen in the form of groundnut cake increased the yield to 1,693 lb. per care (59 per cent) and gave a net profit of Rs. 13-12-0.
(Plate XVII).

Summary

Manurial experiments were carried out at the Rice Research Station Raipur from 1935 to 1943, with the object of ascertaining the effect of (1) fertilizers, (2) organic and inorganic manures and their mixtures, (3) compost and (4) oil-cakes on the yield of paddy.

Fertilizer experiments conducted at the Rice Research Station, Raipur for five years, on light (sandy loam) as well as heavy (clay loam) soils have shown that highest yield and largest net profit are obtained only when nitrogenous and phosphatic fertilizers are given in combination. The most effective nitrogen and phosphate ratio is 1 : 1. The application of 20 lb. nitrogen in the form of ammonium sulphate with 20 lb. phosphoric acid in the form of double superphosphate per acre has given significantly higher yield than either 20 lb. nitrogen or 20 lb. phosphoric acid applied alone. Individually, 20 lb. nitrogen is significantly better than 20 lb. phosphoric acid, and 20 lb. phosphoric acid significantly better than no manure.

The application of 20 lb. nitrogen with 20 lb. phosphoric acid (100 lb. ammonium sulphate with 50 lb double superphosphate) increased the yield of late paddy from 988 lb. to 2,122 lb. per acre, an increase of 115 per cent, and gave a net profit of Rs. 12-15-0 at pre-war rates and Rs. 54-10-0 at the present prices. If the cultivators are not able to use this quantity of fertilizers (costing Rs. 9-12-0 at pre-war rates and Rs. 21 at the present prices) a dressing of at least 50 lb. ammonium sulphate with 25 lb. double superphosphate per acre is recommended. This application of fertilizers will increase the yield, on an average, by 50 per cent and will be definitely profitable. Simplified experiments laid out on cultivators' holdings in 23 important rice, producing tahsils confirmed the above results.

On very light (sandy) soils, phosphoric acid is the limiting factor. The application of 20 lb. P_2O_5 (50 lb. double superphosphate) per acre increased the yield of paddy from 879 lb. to 1,326 lb., an increase of 51 per cent, and gave the largest net profit at pre-war rates. Differences in yields due to the application of 20, 30 or 40 lb. phosphoric acid per acre were, however, not significant.

Very light soils do not respond to the application of nitrogen alone, even to the extent of 40 lb. per acre. The application of nitrogenous fertilizers is, therefore, accompanied with loss. But a combination of nitrogenous and phosphatic fertilizers is very effective in bringing about significant increase in yield over phosphates applied alone or over no manure. On these soils also the most effective nitrogen and phosphate ratio is 1 : 1. The application of 20 lb. nitrogen with 20 lb. phosphoric acid increased the yield of paddy from 879 lb. to 1,582 lb. per acre, an increase of 80 per cent and was profitable.

The application of nitrogenous fertilizers alone, or a mixture of organic and inorganic nitrogen gives significantly higher yield than farmyard manure applied on the same nitrogen basis. The average yield per acre of plots receiving 100 lb. ammonium sulphate (20 lb. N.) was 1,323 lb. and of those supplied with a mixture of 10 lb. nitrogen as farmyard manure with 10 lb. nitrogen as ammonium sulphate, 1,215 lb., against 1,017 lb. of plots receiving 20 lb. nitrogen as farmyard manure. 20 lb. nitrogen per acre applied as farmyard manure gave the same yield as 10 lb. nitrogen supplied as ammonium sulphate, or a mixture of 5 lb. organic and 5 lb. inorganic nitrogen.

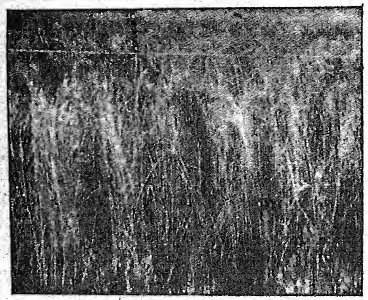
The need for a dressing of nitrogenous fertilizers is, therefore, clearly indicated.

The application of 60 lb. nitrogen in the form of compost (12,000 lb.) increased the yield of paddy from 921 lb. to 1,549 lb. per acre, an increase of 68 per cent and 40 lb. nitrogen in the form of compost (8,000 lb.) increased it to 1,352 lb. per acre, an increase of 47 per cent. The net profits were statistically significant.

EFFECT OF MANURING PADDY WITH GROUNDNUT CAKE

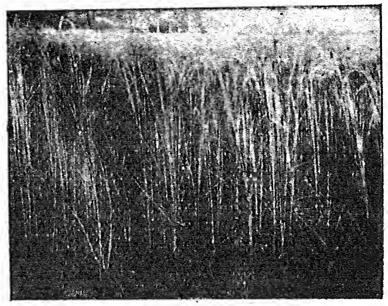
Yield of paddy in lb. per acre

(Average of 3 years, 1942 to 1944)



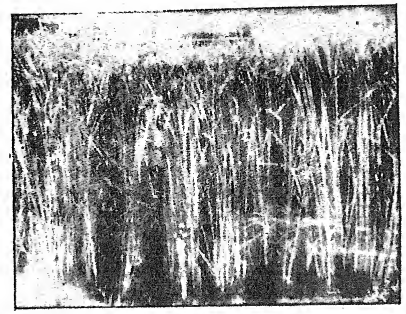
1079 lb.

No manure



1714 lb.

7 maunds cake
(40 lb. N.)



2030 lb.

$10\frac{1}{2}$ maunds cake
(60 lb. N.)

Increase ...	59%	88%
Extra yield ...	635 lb.	951 lb.
	At rates prevailing in December 1943	
Value at 15 lb. a rupee ...	Rs. 42/5	Rs, 63/6
Cost of manure ...	Rs. 28/0	Rs. 42/0
Profit ...	Rs. 14/5	Rs. 21/6

[Rice Research Scheme, C.P.]

APPENDIX A

Mechanical and chemical Analyses of Rice Soils on which manurial experiments were conducted*

Locality	Soil	Depth	Per cent air dry soil passed through 1 mm. sieve: Moisture	Loss on ignition	Clay	Fine silt	Coarse silt	Fine sand	Per 100 gm. soil: Total Ca	Exchangeable Ca	Percentage Total P_2O_5	Percentage available P_2O_5	Loss on ignition per cent	Carbon per cent	C × 1·724	Humus per cent	Organic matter humified per cent	Organic N per cent	C : N ratio	pH value
Labhandi farm, Raipur.	*Matasi*	0in—6 in.	1·07	6·70	25·36	3·7	8·84	58·74	30·5	28·0	·0280	·0141	6·70	·6150	1·060	·206	19·43	·078	7·8	6·8
		6in.—12 in.	2·50	6·09	34·34	3·14	6·78	51·29	17·21	11·55	·540	..	6·09	·5860	1·01	·270	26·73	·08	7·3	7·2
		12in.—18 in.	3·79	8·74	44·79	3·98	7·8	42·67	18·00	17·20	·0342	..	8·74	·4790	0·826	·050	60·56	·072	6·6	7·2
	Dorsa	0in.—6 in.	1·52	3·34	48·26	5·08	7·86	34·86	19·60	19·50	·0321	·0011	3·34	·5750	0·991	·082	8·27	·760	7·5	7·2
		6in.—12 in.	4·35	10·84	50·56	4·36	7·68	32·86	22·60	17·80	·0242	..	10·84	·30	0·517	·062	11·99	·038	7·9	7·4
		12in.—18 in.	4·81	10·34	49·05	4·7	8·63	32·89	34·70	29·99	·0298	..	10·34	·3580	0·617	·036	5·83	·040	8·9	7·4

*Report on the soil-work carried out under the Central Provinces Rice Research Scheme, Raipur, 1942

On light soils, a dressing of 60 lb. nitrogen in the form of groundnut cake ($10\frac{1}{2}$ maunds) increased the yield of paddy from 1,079 lb. to 2,030 lb. per acre, an increase of 88 per cent, and gave a net profit of Rs. 21 at the present prices. 40 lb. nitrogen in the form of groundnut cake (7 maunds) increased the yield to 1,714 lb. per acre (59 per cent) and gave a net profit of Rs. 14.

On heavy soils, *til* (Sesamum) cake sufficient to supply 60 lb. nitrogen (14 maunds) increased the yield of paddy from 1,067 lb. to 2,187 lb. per acre, an increase of 105 per cent and gave a net profit of Rs. 21. 40 lb. nitrogen in the form of *til* cake ($9\frac{3}{8}$ maunds) increased the yield to 1,839 lb. per acre (72 per cent) and gave a net profit of Rs. 16.

Cultivators in the rice tract are therefore advised as follows :

(1) Apply 100 lb. ammonium sulphate with 50 lb. double superphosphate (20 lb. N.+20 lb. P_2O_5) per acre as a top-dressing to paddy in August. This combination of fertilizers will be most profitable.

(2) If it is not possible to use the above quantities of fertilizers, apply at least 50 lb. ammonium sulphate with 25 lb. double superphosphate (10 lb. N. + 10 lb. P_2O_5) per acre.

(3) If superphosphate is not available, apply 100 lb. ammonium sulphate (20 lb. N.) per acre, (except on very light or sandy soils where the application of ammonium sulphate alone will not be profitable).

(4) If the above quantity of ammonium sulphate is not available, even 50 lb. ammonium sulphate (10 lb. N.) per acre can be applied as a top-dressing, preferably after a basal dressing of $1\frac{1}{2}$ carts of farmyard manure (1,250 lb. = 10 lb. N.) per acre.

(5) Prepare compost from waste vegetable matter and apply at the rate of 10 carts (8,000 lb. = 40 lb. N.) per acre.

(6) Apply seven maunds of powdered groundnut cake (40 lb. N.) per acre before transplantation and in *biasi* fields at the time of sowing of seed (1 maund = 82 lb.). On heavier soils, $9\frac{3}{8}$ maunds of *til* cake (40 lb. N.) per acre can also be applied.

Acknowledgements

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The writer is greatly indebted to Mr R. H. Hill, Director of Agriculture, Central Provinces and Berar, for valuable suggestions which have been embodied in this paper. Thanks are also due to Mr R. G. Joglekar, Botanical Assistant, for help in statistical treatment of data.

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A NEW COLORIMETRIC METHOD FOR THE DETERMINATION OF STARCH IN LEAVES AND WOODY TISSUES OF PLANTS

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RECENTLY a method [Chinoy, 1941] was described by which starch in plant material was estimated micro-gravimetrically as starch-iodide. The need for a suitable colorimetric method for the determination of minute quantities of starch was stressed in a previous communication [Chinoy, 1939]. The first pre-requisite for the colorimetric determination of starch is to obtain the starch iodide complex in perfectly colloidal form. This was achieved in the above method by adding an adequate quantity of 0·1. N KI to the starch solution and generating iodine gradually by introducing drop by drop a weak solution of H_2O_2. The clear blue color of starch-iodide thus produced was matched against a standard starch solution similarly treated after the removal of excess of iodine by shaking with $CHCl_3$. This method has been successfully tried in the case of soluble starch, pure natural starches, potato tubers, as well as rice and wheat flours. During the course of work in plant physiology a need was felt for investigating the applicability of this colorimetric method to various plant materials. The technique described here appears to be suitable for general application to plant material.

The stability of starch extracts is also important from the point of view of accuracy in its determination. The analytical work will be greatly facilitated if storage of plant extracts without deterioration can be achieved even for a few days. The use of 21 per cent hydrochloric acid in the cold [Rask, 1927] is open to grave objection as appreciable losses of starch take place by hydrolysis within half-an-hour, even if the solution is kept at a low temperature. Pucher and Vickery [1936] have pointed out difficulties and errors in the use of a concentrated solution of calcium chloride for the extraction of starch. The use of 0·7 per cent KOH which was first suggested by Chinoy, Edwards and Nanji [1934] has been observed to be quite suitable. Attempts have been made here to give experimental proof for the observation.

Extraction of starch from plant material has generally presented difficulties in its determination by the methods involving the specific starch-iodide reaction. This is more so when the plant material is fibrous or woody. Sullivan [1935] in his work on woody tissues of plants, has shown that the size of the particles to which the plant material is reduced before extraction considerably affects the efficiency of the extraction and the accuracy of the subsequent determination. This aspect of the problem has also received attention in this work.

Extraction of starch from plant material

After the preliminary treatment of plant material [Chinoy 1938] an aliquot part 0·1 to 0·3 gm. is moistened with 1-2 ml. of 0·7 per cent KOH, transferred a little at a time into the cup of the micro-macerator, ground to a pasty mass and extracted as reported previously [Chinoy, 1945].

Colorimetric determination of starch

The alkali extracts of plant materials are generally pale to dark yellow and sometimes red. This has been shown to be probably due to the presence of pectins and dextrins [Chinoy, 1938]. Such a colour would obviously be a hinderance in the measurement of the blue colour of starch-iodide. The procedure adopted in the case of natural starches, soluble starch, potato tubers and wheat and rice flours [Chinoy, 1939] had to be modified to overcome the above difficulty. Another source of interference that may be anticipated is from substances of the amylohemicellulose type described by Schulze [quoted from Pucher and Vickery, 1936], Schryver and Thomas [1923] and Ling and Nanji [1925] which occur in certain starch bearing seeds, fruits, leaves and stems. These substances give an intense blue or violet colour with iodine but differ from true starch in that they are not digested by Taka-diastase. A modification of the original method is, therefore, necessary to account for these substances if their presence is suspected.

E

Duplicate aliquots of plant extracts are pipetted out in centrifuge tubes (with tapering ends) and after neutralization of the alkali with the requisite amount of 10 per cent CH_3COOH, 1-2 ml. of 0·1 N iodine and 2-5 ml. of 10 per cent potassium acetate solution are added to precipitate starch-iodide. After standing for an hour or two for coagulation the precipitates are centrifuged for five minutes at 2000 r.p.m. The supernatant clear liquid is siphoned off, and 10 ml. of 30 per cent ethanol are added to the precipitate and, after thorough mixing, it is again centrifuged. After removal of the clear liquid 1 ml. of 0·7 per cent KOH is added to the starch-iodide precipitate and the tube is gently warmed in a water bath (70°-80°C.) for five minutes to remove iodine and gelatinize the starch. On cooling the alkali is neutralized with 10 per cent CH_3COOH and the blue colour of starch iodide is developed by the addition of 1-2 ml. of 0·1 N KI and a requisite amount of dilute (5 volumes) H_2O_2 (about 1 ml.). Standards are prepared as usual by treating a number of aliquots (varying from 1 to 5 ml.) of a standard solution of pure dry rice starch (A.R.) of a known strength with 1-2 ml. of 0·1 N KI and sufficient quantity of H_2O_2 so as to have a slight excess of free iodine in the solution. After allowing the solutions to stand for one hour the excess of iodine is removed by repeated shakings with about 5 ml. of $CHCl_3$. The unknown solutions are then matched against a standard of suitable strength and the starch content as percentage of dry weight of the plant materials is determined by the formula* stated in a previous publication [Chinoy, 1939].

* The formula is reproduced here for ready reference $S—100 \frac{ALV}{GVR}$ where S represents starch content of the material as percentage of dry weight; A, starch in the aliquot of the Standard Solution; V, total volume of the unknown Solution (plant extract); L, colorimetric reading of the Standard Solution; R, colorimetric reading of the unknown Solution; V, aliquot of the unknown Solution taken for comparison and G, plant material in grammes used for preparing the unknown Solution.

The above procedure not only eliminates the colouring matters of the original extract but it also greatly helps to overcome the difficulty which arises in certain cases where it has been observed that alkali extracts of plant material contain some substances which absorb iodine.

In case the presence of amylohemicelluloses is suspected the following procedure is to be followed. An aliquot of a plant extract is neutralized in the usual manner and 1 ml. of a fresh 1 per cent solution of Taka-diastase is added to it and incubated at 37°C. for 1-2 hours, after which the tube is placed in a boiling water bath for five minutes. The above procedure for colour development is followed after cooling the tube. As all the starch will be hydrolyzed by Taka-diastase the development of blue colour will indicate the presence of amylohemicelluloses. The strength of the blue colour in these tubes treated with Taka-diastase can be calculated out in terms of starch and a correction applied to the quantity found in aliquots which are not treated with Taka-diastase. The former gives the value of amylohemicelluloses and the latter gives the value of starch and amylohemicelluloses. Information available in the literature however, point to the fact that the relative proportion of these compounds is usually very small, and therefore no serious error is likely to arise even if their determination is overlooked.

Starch in leaves with special reference to its stability in KOH solution†

Leaves of four different plants, viz. *Lycopersicum esculantum*, *Brassica rapa*, *Trifolium alexandrianum* and *Medicago denticulata*, were used for these experiments. Out of these four the first two were same (Sample No. II in both the cases) as those used in previous experiments [Chinoy, 1938]. After removal of soluble substance by extraction with alcohol, and desiccation and reduction of the sample to 100 mesh grade starch was extracted and determined according to the technique outlined above, in two separate aliquot parts of each sample and in duplicate for each portion. The results are presented in Table I.

Table I

Starch content of leaves

Standard starch solution. 1·5630 mg. in 1 ml. Total volume of extract. 50 ml. in all cases. KOH felatinization: aliquots of extracts neutralized with 10 per cent CH_3COOH just before the addition go 2 ml. of 0·1 N KI + 1-2 ml. of dilute (5 volumes) H_2O_2.

Treat-ment No.	Plant material	Sample analysed gm.	Standard solution ml.	Extract ml.	Colorimetric ratio	Starch percentage (dryweight)
1	*Lycopersicum esculantum* (Tomato leaf No. II— (Chinoy, 1938)	0·2830	1	5	0·9035	5·00
1a	Ditto	0·2830	1	7	1·2820	5·06
2	Ditto	0·2631	1	5	0·8790	5·22
2a	Ditto	0·2631	2	10	0·8835	5·25
3	*Trifolium Alexandrianum*	0·2161	1	5	0·9980	7·22
3a	Ditto	0·2161	2	10	0·9560	6·91
4	Ditto	0·3931	2	5	0·8775	6·98
4a	Ditto	0·3931	2	5	0·8910	7·09
5	*Brassica rapa* (Raddish leaf No. II)— (Chinoy, 1938)	0·2611	1	5	1·0440	6·25
5a	Ditto	0·2611	2	10	0·9420	5·64
6	Ditto	0·2101	1	5	0·9080	6·75
6a	Ditto	0·2101	2	10	0·8955	6·66
7	*Medicago denticulata*	0·3551	2	5	0·8750	7·70
7a	Ditto	0·3551	2	5	0·8890	7·83
8	Ditto	0·2005	1	5	1·0350	8·07
8a	Ditto	0·2005	2	10	1·0030	7·82

This may be numbered part III of the series of which parts I and II appeared elsewhere [Chinoy 1939].

Agreement between the duplicates of the same sample is good. Even separate aliquots vary within 1 to 5 per cent. In treatment No. 5a some error appears to have been made in the colorimetric reading. Close agreement between starch contents of separate aliquots of the same sample suggests that it becomes quite homogeneous if passed through a 100-mesh sieve.

As already stated storage of plant extracts without deterioration will greatly facilitate work. Starch is known to be fairly stable in an alkaline medium. As no data on the stability of starch under the conditions of these experiments was available, it appeared of interest to study this question. Plant extracts used for determinations of starch in Table I were stored in well stoppered glass bottles without neutralization of alkali and aliquots were removed from them at different intervals of time, neutralized and starch estimated as usual. Four such determinations were made at intervals of 4, 8, 15 and 25 days respectively after storage. Results appear in Table II.

TABLE II

Starch content of the same extracts as shown in Table I after storage—

Standard starch solutions : 1·5630, 1·372, 1·430 and 1·3823 mg. per 1 ml. in 4, 8, 15 and 25 days storage sets respectively (fresh solutions except in the first set).

Total volume of the extract : 50 ml.

KOH gelatinization: aliquots of extracts neutralized with 10 per cent CH_3COOH just before the addition of 2 ml. of 0·1 N KI + 1-2 ml. of dilute (5 volumes) H_2O_2.

Starch content determined after storage for:

Treat-ment No. (Table I)	Standard Solution (ml.)	Ex-tract (ml.)	4 days		8 days		15 days		25 days	
			Colori-metric Ratio	Starch percent-age (dry wt.)	Colori-metric Ratio	Starch per cent age (dry wt.)	Colri-metric Ratio	Starch percent age (dry wt.)	Colori-metric Ratio	Starch percent-age (dry wt.)
1	1	5	0·8856	4·89	1·0300	5·00	0·9110	4·61	0·8030	3·93
2	1	5	+ ·8785	5·22	0·9990	5·21	0·8670	4·71	0·7590	4·00
3	1	5	0·9885	7·15	1·1220	7·12	0·9940	6·58	0·9130	5·84
4	2	5	0·8760	6·97	1·0050	7·02	0·8630	6·28	0·7570	5·32
5	1	5	1·0420	6·24	1·1820	6·20	1·1120	6·08	0·9420	5·00
6	1	5	0·9375	6·97	1·0620	6·92	0·9490	6·47	0·8260	5·45
7	2	5	0·8795	7·74	0·9985	7·71	0·8925	7·18	0·7790	6·06
8	1	5	1·0370	8·08	1·1670	7·97	1·0600	7·56	0·8855	6·11

It will be observed that there is very little deterioration of starch till the 15th day. The values are however slightly lower in most cases suggesting that degradation of starch has just begun. After 25 days of storage there is a definite decline in the values of starch. There is an indication that the losses are some what proportional to the concentration of starch in the alkali solution. The greater the concentration of starch, the greater is the loss in a given time.

Effect of size of particle on the determination of starch content of woody tissues

Terminal shoots of *Bombax malbaricum*, *Ficus religiosa*, and *Mengifera indica* were collected in the month of February (about two months before flowering). After the usual preliminary treatment the dried sample was powdered to pass through a 40-mesh sieve. One third portion of this sample was taken out and the remainder of the sample was further reduced till the whole of it passed through a 60-mesh sieve. It was then again divided (after thorough mixing) into two parts. One of them was stored for starch extractions and the other was further reduced to pass through a 100-mesh sieve. In this manner three grades of powders were obtained from each plant sample. Although the 40-and 60-mesh portions contained particles smaller than its own grade a 100-mesh sample did not contain any particles of these two grades. Aliquots of these graded samples were then crushed to a pasty mass by the technique described elsewhere [Chinoy 1945] and starch was estimated colorimetrically as shown above. The results are presented in Table III.

Statistical analysis of results

Analysis of variance [Fisher 1939] were carried out on data presented in Tables I, II and III in order—(1) to obtain a correct estimate of errors of determination, (2) to determine the period beyond which storage of alkaline starch solutions caused significant reduction in starch content due to its deterioration and (3) to determine size of the sieve mesh which significantly reduced the accuracy of starch determination. Results are presented below (Table IV to VIII).

TABLE III

Effect of particle size on determination of starch in woody tissues

Standard starch solutions : (1) 2·722 mg. per 1 ml. and, (2) 1·364 mg. per 1 ml.
Total volume of the extract : 50 ml. in all cases—
KOH gelatinization : Aliquots of extracts neutralized with 10 per cent CH_3COOH just before the addition of 2 ml. of 0·1 N KI + 1-2 ml. of dilute (5 volumes) H_2O_2.

Plant Material	Plant samples passed through sieve of														
	100-mesh					60-mesh					40-mesh				
	Sample analyzed in gm.	Standard solution in ml.	Extract in ml.	Colorimetric ratio	Starch percentage (dry wt.)	Sample analyzed in gm.	Standard solution in ml.	Extract in ml.	Colorimetric ratio	Starch percentage (dry wt.)	Sample analyzed in gm.	Standard solution in ml.	Extract in ml.	Colorimetric ratio	Starch percentage (dry wt.)
Ficus religiosa—terminal shoots.	0·1713	1 (2)*	5	1·0545	8·39	0·1821	1 (2)*	5	1·0460	7·83	0·1561	1 (2)*	5	1·0460	9·14
,, ,, ,, ,,	0·2387	2 (2)	5	0·7590	8·67	0·7672	2 (2)	5	0·8250	8·42	0·2103	1 (2)	5	1·1070	7·18
Bombax malbaricum—terminal shoots.	0·2401	1 (1)	5	0·8070	9·15	0·1840	1 (1)	10	1·1470	8·48	0·2621	1(1)	5	0·8365	8·69
,, ,, ,, ,,	0·2401	1 (1)	5	0·7920	8·98	0·1840	1 (1)	10	1·0940	8·09	0·2621	1 (1)	10	1·6460	8·55
,, ,, ,, ,,	..	..	..	..	..	0·2160	1 (1)	10	1·1070	6·97	0·1823	1 (1)	10	0·9070	6·77
,, ,, ,, ,,	..	..	..	..	..	0·2160	1 (1)	10	1·0780	6·79	0·1823	1 (1)	10	0·9030	6·74
Mengifera Indica—terminal shoots.	0·1701	1 (1)	5	0·8380	13·41	0·2541	1 (1)	5	1·3215	14·16	0·3221	1 (1)	5	1·1090	9·37
,, ,, ,, ,,	0·1701	1 (1)	5	0·8160	13·06	0·2541	1 (1)	5	1·2760	13·67	0·3221	1 (1)	5	1·0980	9·28
,, ,, ,, ,,	..	..	..	..	..	0·1731	2 (2)	5	0·8180	12·89	0·2012	2 (2)	5	1·0350	13·41

*Figure in parenthesis indicates the number of the Standard solution.

TABLE IV

Analysis of variance of data in Table I—
Mean starch content=6·59 per cent dry wt.

Factor	Degrees of freedom	Sum of square	Mean square	Treatment variance / Error variance	Value of F (p=0·01)
Plant material	3	16·03	5·340	87·54	6·99
Experiments	3	0·38	0·127	2·08	6·99
Error	9	0·55	0·061	..	..
TOTAL	15	16·96	..	..	..

S. E. of experiments 0·178.

The ratio of variance of experiments and error variance is not significant. It therefore follows that variations between different determinations are errors of sampling. The standard error is 2·7 per cent of the general mean. There are highly significant differences in starch contents of different plant materials.

TABLE V

Analysis of variance of data presented in Table II—
Mean starch content=6·26 per cent dry wt.

Eight readings for starch content of fresh solutions corresponding to values for four other storage times have been obtained by taking the average values for eight treatment numbers of Table I.

Factor	Degrees of freedom	Sum of square	Mean square	Treatment variance / Error variance	Value of F (p=0·01)
Plant material (P)	3	37·15	12·380	154·75	4·94
Time of storage (T)	4	11·49	2·870	35·87	4·43
Interaction P×T	12	1·20	0·100	1·43	..
Error	20	1·43	0·015	..	..
TOTAL	39	51·27	..	..	..

TABLE VI

The standard in this case is the mean starch content of fresh plant extracts from Table I (6·59 per cent dry wt.)

Time of storage	Mean starch content (per cent dry wt.)	Mean percentage of standard
0	6·590 (Standard) (Table I)	100·0±1·435
4	6·660	101·0±1·435
8	6·645	100·8±1·435
15	6·190	93·6±1·435
25	5·215	79·0±1·435

There is a highly significant effect of storage time. Starch contents of different plant materials vary significantly. S.E. of mean for storage time works out to be 0·0946 which is the mean of values given in Table I and which has been taken as the standard.

For further clarification the mean starch contents for different storage times have been expressed as percentages of the standard treatment.

The standard error of each mean expressed as a percentage of the standard is 1·435 per cent. The standard error of the difference between any two means is 2·03 per cent. A difference between the percentage values greater than 4·23 (C.D.) is therefore significant. It will be seen from Table VI that only after 15 days storage of plant extracts a significant lowering of starch content takes place. No deterioration is observed even after storage for eight days. Starch is therefore very stable in an alkaline solution.

TABLE VII

Analysis of variance of data presented in Table III

Mean starch content = 9·7 per cent dry wt.

Factor	Degrees of freedom	Sum of square	Mean square	Treatment variance / Error variance	Value of F ($p = 0{\cdot}01$)
Plant Material (P)	2	55·42	27·71	98·4	8·02
Sieves (S)	2	9·363	4·682	16·58	8·02
Interaction P × S	4	15·892	3·973	14·07	6·62
Error	9	2·535	0·282	..	..
TOTAL	17	83·21	..	..	..

Highly significant differences are obtained for plant material. Sieve and their interaction. As the interaction is significant it appears that the relative hardness of the material will also affect the size and shape of particles passing through a sieve of certain mesh and consequently will influence the accuracy of starch determination. This has also been pointed out elsewhere [Chinoy 1942].

Mean starch contents for different sieve mesh have been presented in Table VIII as percentages of the standard treatment which is in this case the mean starch content of samples screened through a 100-mesh sieve.

TABLE VIII

Sieve	Mean starch content (percentage dry wt.)	Starch content (percentage of standard)
100-mesh	10·28 (Standard)	100·1±2·11
60-mesh	10·11	98·5±2·11
40-mesh	8·70	84·5±2·11

Standard error of each mean expressed as percentage of the standard is 2·11. The standard error of difference of any two means is 2·99. A difference between percentage values greater than 6·79 (C.D.) is therefore significant. Results of starch content are therefore significantly low for samples screened through 40-mesh sieve.

It is clear that the grade to which the material is initially reduced has considerable influence on the accuracy with which starch can be determined. In 100-mesh samples the error of separate determinations is within 3 per cent [also see Chinoy, 1938 and 1941]. Error in starch determination sharply increases with the coarseness of the powder.

Discussion of the results

The new colorimetric method involving the use of 0·1 N KI and dilute H_2O_2 for the development of starch-iodide colour gives satisfactory results in the case of leaf material and woody tissues of plants (Tables I and III). Although the use of the micro-macerator [Chinoy, 1945] for reducing the plant material has considerably facilitated extraction work, the accuracy of a starch determination depends upon the size of particles in a sample. The results (Table III) showing the influence of particle size on starch content are substantially in agreement with those of Sullivan [1935]. They clearly demonstrate the fact that in all analytical work of value the sample must be reduced to pass through a 100-mesh sieve before reliable results can be obtained. The disintegration of the plant material by the micro-macerator combined with the macerating action of alkali removes even the last traces of starch from the hardest of plant parts.

The results in Table II leave no room for doubt regarding the stability of starch in alkaline solution at least for about two weeks. This fact gives a considerable advantage to this method over other methods for starch extraction using concentrated. $CaCl_2$ and 21 per cent HCl as solvents [Rask, 1927 and Pucher and Vickery, 1936].

The stability and the specificity of the blue starch-iodide colour have already been established in previous communications [Chinoy, 1939] and therefore a determination by this method gives the value of ' true ' starch.

Interference in the above blue reaction by amylohemicelluloses is rarely met with and the procedure described here can effectively meet it if necessary.

Summary

1. A new colorimetric method for the determination of minute quantities of starch in leaves and woody tissues is described, where the starch-iodide colour is developed by the addition of KI and H_2O_2 in requisite quantities to generate a slight excess of free iodine.

The colour of starch-iodide is matched in a colorimeter against that of a standard starch solution similarly treated after removal of excess of iodine by chloroform.

2. Data have been presented to show the stability of starch in 0·7 per cent KOH solution. Starch solutions can be stored for about a fortnight without deterioration.

3. Size of particles in a plant sample considerably influences the accuracy of starch determination. For accurate analytical work the sample must be reduced to pass through a 100-mesh sieve.

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AN APPLICATION OF DISCRIMINANT FUNCTION FOR SELECTION IN *DURUM* WHEATS*.

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SELECTION for high yield in cereals is one of the chief considerations in plant breeding programme, though there are characters like resistance to diseases or grain quality in wheat which are also important.

Yield in wheat depends upon the number of tillers and ears per plant, number of grains per ear, and weight of grain (usually estimated as weight of 100 grains). A high yielding variety, therefore, should have large number of tillers and ears per plant, more grains per ear and high grain weight, but since the observed variability of the individual characters may be partly genetic and partly environmental, and since characters like the mean number of tillers and ears per plant, and number of grains per ear are highly affected by environmental conditions, plant selections made in the fields on the basis of such observable characters, which are subject to a large non-heritable variability, may not be efficient. It has, therefore, been suggested that, first, the selection for high yield should be made on the basis of such of the characters as are least affected by environmental conditions, and secondly, when selection is based on several characters simultaneously, the degree of correlation between pairs of different characters should also be considered. Finally, the theoretical weights attached to the different characters used simultaneously in selection should be such that the observed value of a plant or a progeny is highly correlated with its genetic value.

In the past, ratios such as the migration coefficients [grain : total produce, Beaven, 1920] or the survival rate of tillers [Bell, 1937 ; Hunter, 1938] were used as selection indices for evaluating the yielding potentialities of different varieties or lines, but these ratios are of an arbitrary nature, and do not reflect any correlation between the characters and the yield. What we want is to find out a method of selection which would give maximum weightage to (a) those component characters which are least affected by environmental conditions and (b) those characters which show least mutual correlations.

The discriminant function [Fisher, 1936] provides exactly such a method in which both these factors are taken into account. In the linear formula consisting of these characters on which selection is to be based, the relative weights of the observed values of the different characters are so fixed that the resulting compound score is most highly correlated with the genetic value of a variety or line.

The expected genetic improvement for any given selection intensity has always been found to be greater when selection is done with the help of discriminant function than when it is done directly on the observed characters. This is what should be expected, as this function is more highly correlated with the genetic value of the variety or line than any other formula devised for the purpose of selection. The application of the method for plant selection has been developed by Smith [1937] who illustrates its use on wheat. The object of the present study is to work out a discriminant function in relation to selection for high yield in Central India *durum* wheats.

THE THEORY OF THE DISCRIMINANT FUNCTION

If a variety or line of wheat is measured in η characters say $\chi, \chi_2 \ldots x_n$, then the genotopic yield value of the variety ψ (psa) can be scored as

$$\psi = a_1 z_1 + a_2 z_2 \ldots\ldots\ldots\ldots\ldots\ldots a_n z_n \ldots\ldots\ldots\ldots\ldots (1)$$

when $+ai$ is the value of x to be expected due to genotype and $a_1 a_2 \ldots\ldots a_n$ are the relative weights attached to these characters.

* Part of the thesis submitted to the Nagpur University for the degree of Master of Science in Agriculture (1944).

Since the genotypes cannot be measured or observed, this genotypic yield value of the variety can only be estimated from the mean values of the different characters of the progenies, and these observed values are affected by environment and may also be mutually correlated. On account of these factors, the phenotypes have to be scored according to the equation—

$$Y = b_1x_1 + b_2x_2 \ldots\ldots\ldots\ldots\ldots b_nx_n \ldots\ldots\ldots (11)$$

in which, with the help of discriminant function technique, the coefficients $b_1 \ldots b_n$ are so evaluated that the compound score ψ is most highly correlated with μ, the true genetic yield value of the variety or line.

The two covariance matrices necessary for setting up simultaneous equations to evaluate the coefficients $b_1 \ldots\ldots b_n$ are obtained from the mean squares and mean products of varieties or lines and of error for different characters measured in replicated field tests. The details of the calculations are fully described by Smith [1937].

Smith [1937] has also given the expectation of genetic advance by selection with the help of discriminant function over the mean of the original population as $Z/Q\ BV^{\frac{1}{2}}$ when Z and Q are determined by the degree of selection applied, Q representing the intensity of selection and Z, the ordinate of the unit normal curve at the deviate determined by the selection intensity. Once this intensity is fixed, the value of Z can be obtained from a table of normal probability integral. B is the coefficient of regression of the true genetic value on the compound score used for selection and V is the variance of the score between the progenies.

Experimental material

In order to work out a discriminant function for selection in *durum* wheats, sixteen one pound samples of local and improved strains of *durum* wheats, listed in Table I were obtained from Indian States and British Provinces in 1941. The samples were grown along with two of the Institute *durum* wheats, namely Rewa 42 and Dhar Selection, in five randomized blocks on the 29th October, 1941. The size of the plot was 7 ft. × 25 ft. and block size 63 ft. × 50 ft., plots being arranged in two rows in each block. Sowing was done as usual at the rate of 50 lb. per acre. When the germination was complete, a count of plants germinated was taken in four experimental lines, leaving one line on either side and two feet at each end of the plot as non-experimental margins.

TABLE I

List of durum *wheats worked with*

Name of place	Name of strain	Name of place	Name of strain
1. Bengal	Gangajali 50	10. Hyderabad (Deccan)	Parbhani 1
2. Ditto	Gaithi 29	Ditto	Ditto 2
3. Bombay	Niphad 81	11. Ditto	Ditto 2
4. Ditto	Bansi 168	12. Ditto	Ditto 3
5. Ditto	Bansi 224	13. Ditto	Ditto 4
6. Ditto	Bansipilli 808	14. Ditto	Ditto 6
7. Central Provinces	Bansi local ..	15. Ditto	Ditto 7
8. Institute of Plant Industry	Rewa 42	16. Ditto	Ditto 8
9. Ditto	Dhar Selection ..	17. Ditto.	Local
		18. Ditto	Bansi local

From each plot, after thinning out the plants wherever they were in bunches and leaving only singles, twenty plants were selected at random for observations which were then properly labelled for further studies. There were in all 100 plants for each sample. When the crop was ready for harvest which was in the first week of March 1942, the labelled plants were first harvested individually. Mean number of tillers and ears per plant, mean number of grains per ear, and mean weight of 100 grains, besides mean weight of grain and straw per plant were recorded and analyzed statistically.

Results

Statistical analysis of the observations recorded on each sample for each character was done, and the variances and covariances are given in Tables II and III respectively.

Table II

Analysis of variance of the mean number of tillers and ears per plant, number of grains per ear, weight of 100 grains and weight of grain and straw per plant of Provincial durums

Due to	d.f.	Mean number of tillers per plant		Mean number of ears per plant		Number of grains per ear		Mean weight of 100 grains in gm.		Mean weight of grains per plant in gm.		Mean weight of straw per plant in gm.	
		Mean Squares and variance ratios											
		M. S.	V. R.	M. S.	V. R.	M. S.	V. R.	M. S.	V. R.	M. S.	V. R.	M. S.	V. R.
Varieties . .	17	1·2679	4·18**	1·1372	8·29**	40·1953	2·84**	1·2696	8·19**	1.2311	2·93**	3·6296	2·75**
Error . .	68	0·3032	..	0·1371	..	14·1096	..	0·1549	..	0·4189	..	1·3180	..

**Significant at 1 per cent level. $n_1=12$ and $n_2=70$ P = 2.45 at 1 per cent

Differences between the varieties for mean number of tillers and ears per plant, number of grains per ear, weight of 100 grains and mean weight of grain and straw per plant are highly significant indicating that the varieties are distinctly different in all characters. These differences are of very high order for mean number of ears per plant and weight of 100 grains.

Correlation coefficients were determined between pairs of different characters for varieties and also for Error (Table III). The correlation coefficients for varieties are positive and significant between number of total tillers at harvest and number of ears, between number of tillers and weight of straw at 1 and 5 per cent respectively. This is to be expected as number of ears and weight of straw are both dependent upon the number of tillers produced. Between number of tillers and number of grains per ear the coefficient is negative and significant at 5 per cent indicating that varieties with high tiller number have fewer grains per ear. The number of tillers is positively correlated with the weight of 100 grains but the coeficient is small and non-significant. The correlation between the number of ears and the numbers of grains per ear is negative and significant at 5 per cent. This is to be expected on account of positive and significant correlation between the number of tillers and the number of ears per plant mentioned above. Between the number of ears and the weight of straw the correlation is significant and positive, between the number of ears and the weight of 100 grains it is positive and non-significant. There is no significant correlation between the number of grains per ear and the weight of 100 grains. Between the number of grains per ear and the weight of straw the correlation is negative and non-significant. The weight of 100 grains has no significant correlation with the weight of straw.

The correlation coefficients between pairs of different characters in the Error line of the analysis are of the same signs as for varieties, except between the number of tillers and the weight of 100 grains, between the number of ears and the number of grains per ear and between the number of grains per ear and the weight of straw, but the last alone is significant.

Correlation coefficients between the number of tillers and the weight of 100 grains are non-significant and of a very small magnitude both for the varieties and for error. The correlation between the number of ears and the number of grains per ear is negative and significant for varieties, but positive and non-significant for error. Between the number of grains per ear and the weight of straw the correlation coefficients both for varieties and for error are of the same magnitude, but for varieties the coefficient is negative and non-significant. When the correlation between the varieties differs from the corresponding correlation in error part of the analysis, the differences must be interpreted as being due to the difference between genetic associations, that is, those due to linkage or similar causes and physiological relationship. To illustrate the difference, the correlation between the number

TABLE III

Analysis of covariance between the number of tillers and ears per plant, number of grains per ear, weight of 100 grains and straw per plant of Provincial durums

Due to	d.f.	No. of tillers × No. of ears		No. of tillers × No. of grains per ear		No. of tillers × Weight of 100 grains in gm.		No. of tillers × weight of straw in gm.		No. of ears × No. of grains per ear		No. of ears × Weight of 100 grains in gm.		No. of ears × weight of straw in gm.	
		Mean product	r	Mean product	r	Mean product	r	Mean product	r	Mean product	r	Mean product	r	Mean product	r
Varieties	17	+1·1109	+·9252**	—3·7297	—·5224*	+·0790	+·0622	+1·1072	+·5161*	—3·7729	—·5580*	+·1165	+·0960	+1·2996	—·63
Error	68	+0·1215	+·5961**	—0·1097	—·0530	—·0126	—·0581	+·2090	+·3306**	+·2249	+·1617	+·0309	+·2120	+·2905	+·683

Due to	d.f.	No. of grains per ear × Weight of 100 grains in gm.		No. of grains per ear × Weight of straw in gm.		Weight of 100 grains in gm. × Weight of straw in gm.	
		Mean products	r	Mean product	r	Mean product	r
Varieties	17	+·7936	+·1110	—3·0763	—·2546	+·9462	+·4407
Error	68	+·0056	+·0037	+1·2115	+·2890*	+·1012	—·2239

$n=16$, $r=\cdot4683$ and $\cdot5897$ for 5 per cent and 1 per cent respectively. $n=70$, $r=\cdot2319$ and $\cdot3017$ for 5 per cent and 1 per cent respectively.

* Significient at 5 per cent level.
** " at 1 per cent "

of ears per plant and the number of grains per ear may be quoted. Between varieties, there is a significant negative correlation between the two characters showing that the varieties with a large number of ears per plant have fewer grains per ear, but the error correlation is positive and non-significant showing that the relationship between the characters is not of a physiological nature, and we consequently expect to obtain plants with a large number of ears also having a large number of grains per ear. A similar explanation fits in for the difference between the number of grains per ear and the weight of straw. On the other hand the correlation between the mean number of ears per plant and the weight of straw per plant is positive and of almost the same magnitude both for varieties and for error. This simply means that plants with a large number of ears must also possess a large weight of straw which is to be expected. The same relationship is shown by varieties as well.

Such correlations can give us information only about the simple associations (negative or positive) between pairs of different characters, but only by means of a method like the discriminant function can we take into account the effect of selection in one character on the compensating changes in other characters, and ensure efficient selection for improvement with which we are concerned.

The grain yield of wheat is the product of number of ears per plant × number of grains per ear × weight of each grain. When these are transformed into logarithms, the logarithm of yield can be expressed as sum of the logarithms of these components, that is, *log* yield=*log* ear number + *log* grain number+*log* grain weight. This equation enables us to introduce some more characters which though they do not directly contribute to yield of grain may give us additional information on account of their correlation with other characters. The coefficients of such additional characters will be zero, and those of the components of yield as 1. Since antilogarithm of zero is 1, the product of of these components of yield will not change with the introduction of such additional characters.

The number of tillers and ears per plant, the number of grains per ear, the weight of 100 grains and the weight of straw per plant for each of the five blocks were converted into logarithms, and then analysed statistically, and variances and covariances between all pairs of characters were obtained.

We, therefore, take as our variates

x_1 logarithm of mean number of tillers per plant
x_2 ,, ,, ,, ,, ear ,,
x_3 ,, ,, ,, ,, grains per ear
x_5 ,, ,, weight of 100 grains (in gm.)
x_5 ,, ,, ,, ,, straw per plant (in gm.)

Our equation, therefore, for grain yield is

$$\psi = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5$$

Where $a_1 = a_5 = 0$ and $a_2 = a_3 = a_4 = 1$

We, then obtain the values of coefficient b from the following formula,

$$Y = b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$$ as described below :—

The mean squares and mean products in the varietal line of the analysis of variance and covariance termed tij are given in Table IV below :

TABLE IV

The mean squares and mean products in the varietal line of analysis of variance and covariance—tij

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm. 4	Weight of straw in gm. 5
Tillers	1	0·0219	0·0229	—0·0058	0·0015	0·0156
Ears	2	..	0·0302	—0·0121	0·0004	0·0241
No. of grains per ear	3	..	..	0·0150	0·0018	0·0069
Weight of 100 grains in gm.	4	..	..	..	0·0148	0·0107
Weight of straw in gm.	5	..	..	..	..	0·0472

From each row of Table IV sets of equations are formed similar to the sets of simultaneous equations formed in solving partial regression equations for obtaining c values [Fisher 1938]. These values of *c* thus obtained are given in Table V below :

TABLE V

The value of cij.

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm. 4	Weight of straw in gm. 5
Tillers	1	380·77	—400·37	—134·09	—64·70	73·64
Ears	2	..	505·30	187·42	89·91	—118·66
No. of grains per ear	3	..	..	149·26	14·04	—32·74
Weight of 100 grains in gm.	4	..	..	..	103·14	—45·85
Weight of straw in gm.	5	..	..	..	..	63·04

The mean squares and mean products for error in the analysis of variance and covariance are termed *cij*. When these are substracted from the corresponding values of *tij* (Table IV), we get the genetic component of mean squares and mean products for the varieties, which are termed *gij* (Table VI).

TABLE VI

The values of gij

i	j	Tillers	Ears	No. of grains per ear	Weight of 100 grains in gm.	Weight of straw in gm.	*A* factors
Tillers	1	0·0166	0·0204	— 0·0048	0·0023	0·0138	0·0179
Ears	2	..	0·0261	— 0·0133	—0·0001	0·0178	0·0127
No. of grains per ear	3	..	..	0·0086	0·0017	—0·0111	0·0030
Weight of 100 grains in gm	4	..	..	..	0·0129	—0·0089	0·0145
Weight of straw in gm.	5	..	..	..	..	0·0274	0·0156

By multiplying *gij* values of each row in Table VI with the corresponding theoretical weights *aj* attached to each character, the values of *A* factors are obtained and are given in the last column of Table VI. For example,

$$A_1 = a_1g_{11} + a_2g_{12} + a_3g_{13} + a_4g_{14} + a_5g_{15}$$
$$= 0 \times 0{\cdot}0166 + 1 \times 00{\cdot}204 — 1 \cdot \times 00048 + 1 \times 0{\cdot}0023 + 0 \times 0{\cdot}0138$$
$$= 0{\cdot}0227 — 0{\cdot}0048 = 0{\cdot}0179$$

Similarly $A_2 = 0{\cdot}0127$

$A_3 = 0{\cdot}0030$

$A_4 = 0{\cdot}0145$

$A_5 = 0{\cdot}0156$

The values of coefficient *b* are then obtained by multiplying these *A* factors with *cij* (Table V) as follows ; and are given below :

Tillers. $b_1 = A_1c_{11} + A_2c_{12} + A_3c_{13} + A_4c_{14} + A_5c_{15}$

$= 0{\cdot}0179 \times 380{\cdot}77 — 0{\cdot}0127 \times 400{\cdot}37 + 0{\cdot}0030 \times 134{\cdot}09 — 0{\cdot}0145 \times 64{\cdot}70$
$+ 0{\cdot}0156 \times 73{\cdot}64 \quad = +2{\cdot}3440$

Ears, b_2 $= —1{\cdot}8589$

Number of grains per ear b_3 $= —0{\cdot}7749$

Weight of 100 grains (in gm.) b_4 $= +0{\cdot}7218$

Weight of straw (in gm.) $b_5 \quad = +0\cdot2280$

Substituting these values of b in the equation

$Y = b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$

the linear function of the characters x_1 to x_5 is obtained as follows:

$Y = 2\cdot3440X_1 - 1\cdot8589X_2 - 0\cdot7749X_3 + 0\cdot7218X_4 + 0\cdot2280X_5$ (i)

When samples are scored with the help of this function the values so obtained will be highly correlated with the genotypic values of the samples, and will show the yield potentialities of the various samples.

If the mean number of tillers are omitted from the data as number of tillers and ears are highly correlated, the coefficients of linear function can be recalculated, and are given below:

$Y = 0\cdot6058X_2 + 0\cdot0506X_3 + 1\cdot1201X_4 - 0\cdot2253X_5$ (ii)

With the help of these functions, we can now obtain scores for each variety or line by substituting the mean values of characters x_1x_2, x_3, x_4 and x_5, the scores thus obtained will represent the inherent value of the variety or line. In respect of tiller and ear number, weight of 100 grains and weight of straw the scores will be affected roughly in proportion to the magnitude of the coefficients, as mean values of the characters are of the same order, that is, the mean number of tillers ranges from 2·41 to 4·63, the mean number of ears from 1·82 to 3·79, the mean weight of 100 grains from 3·31 to 5·35 gm., and the mean weight of straw from 2·48 to 6·03 gm., but the values of the scores will be influenced to a greater extent than expected from the magnitude of the coefficients of grain number per ear, as the mean of this character which ranges from 17·33 to 28·16 is about seven to eight times the mean of other characters.

It will thus be observed that plants selected with the help of function (i) will improve the yield when the basis of selection is high number of tillers and high grain weight, while high ear number and high grain number per ear will decrease it. If tillers are omitted from consideration, and selection is done with the help of function (ii), then high ear number and high grain weight should be the basis of selection. Selection for high grain number per ear will not show appreciable change as its coefficient is very small.

Genetic advance

By genetic advance we understand improvement achieved through selection, and its magnitude may be estimated by the percentage excess in the mean yield of the progenies of the selected plants over the mean yield of the original unselected material. When the varities are evaluated with regard to their yield potentialities by means of discriminant function which gives for each variety or line a score highly correlated with the genotypic value of the variety or line or by ordinary selection in which the varieties are scored on the basis of observed values of different characters assuming these to be the best expressions of the genotype, the difference between these two procedures of selection may be expressed algebraically as the difference between the following two expressions:

(i) formula for discriminant function, $Y = b_1x_1 + b_2x_2 + \ldots b_nx_n$

(ii) formula for ordinary selection $Y = a_1x_1 + a_2x_2 + \quad \ldots a_nx_n$

Where $x_1x_2 \ldots x_n$ represent in both formulae the mean performance of the progenies for the characters, $b_1b_2 \ldots b_n$ in formula (i) are the coefficients obtained by the discriminant function technique and $a_1a_2 \ldots a_n$ in formula (ii) are the theoretical weights attached to these characters.

The greater efficiency of the discriminant function will be reflected in the greater magnitude of genetic improvement brought about when selection of a given intensity is made with the help of discriminant function instead of being based on the apparent value of the material. This point is discussed below:

The expectation of genetic advance by discriminant function over the mean of original population is shown to be $Z/QBV^{\frac{1}{2}}$ [Smith, 1937], assuming the original population to be normally distributed, when Q represents the fraction of the population selected, and Z the ordinate of the unit normal curve at the deviate determined by the selection intensity, and B is the regression coefficient of the true genetic value ψ on the compound score Y, that is $B = W/V$, where W is the covariance of ψ and Y and V the variance of Y.

When the intensity of selection is fixed, the values of Z and Q are constant, and the expectation of genetic advance is proportional to the quantity $B\sqrt{V}$ which alone need be calculated. Table VII shows this quantity after conversion into original units and the percentages of excess of genetic advance by discriminant function over ordinary selection.

TABLE VII

The quantity $B\sqrt{V}$ after conversion into original units and the percentage of excess of genetic advance by discriminant function over ordinary selection

Characters	Index of genetic advance		Percentage excess of advance by discriminant function
	Discriminant function	Ordinary selection	
All five characters	1·536	1·320	16·4
Four characters (tillers omitted)	1·388	1·320	5·2

In calculating the values of $BV^{\frac{1}{2}}$ for ordinary selection numerical values of a, coefficients are used in place of the value of b, coefficients used in discriminant function.

The greater efficiency of the discriminant function is clearly brought out in Table VII, particularly when all the five characters, namely, tiller number, ear number, number of grains per ear, the weight of 100 grains and the weight of straw are involved. When the tiller number is omitted from the analysis, the discriminant function is superior by about 5 per cent. This difference brings out the importance of tiller number in selection for higher yield. Tiller number is obviously strongly correlated with yield and whereas we can with the help of a discriminant function take this character into account in making selection, we do not utilize this information in adopting the ordinary method of selection.

We may conclude from the experiment on provincial *durums* that selection in *durums* should be done on the basis of high tiller number and high grain weight.

MALVI SELECTIONS

Data from one more experiment which included selections from a local sample of a particular area were analyzed to work out a discriminant function, and is described briefly below:

Seventy-two single ear bulks from a local *durum* wheat were grown with Indore local as a control in a Symmetrical Incomplete Randomised Block experiment in 1940-41 with nine groups. The details of writing out sets and the procedure of analysing the data are given in Fisher [1938], Fisher and Yates [1938.]

The experiment was sown on the 14th October, 1940 and was harvested on the 5th March, 1941. The size of each plot was 14 in. × 11 ft. and the block size 10 ft. 6 in. × 11 ft. One foot at each end of the plot and one row of local wheat on either side of the block were discarded as non-experimental margins. In each plot, after the germination was complete, a count of plants was taken and before the plants started tillering a random foot number was selected and fifteen plants beginning from this mark, which represented about 12 per cent of the average total number of plants per plot, were counted and demarcated by two wooden pegs fixed on either side of the sampling units, for observations like tillers etc. Before the crop was harvested, total number of tillers and ears per sampling unit were counted, and after the harvest, mean number of grains per ear and mean weight of 100 grains were recorded and the data analyzed statistically. The analysis of variance for different characters are given in Table VIII. Differences between the number of tillers and ears per plant, the number of grains per ear and the weight of 100 grains are highly significant indicating that progeny bulks differ among themselves widely in all characters.

TABLE VIII

Analysis of variance for number of tillers and ears per plant, number of grains per ear and the weight of 100 grains of Malvi selections

Due to	d.f.	Mean squares and variance ratios							
		Number of tillers per plant		Number of ears per plant		Number of grains per ear		Weight of 100 grains in gm.	
		M.S	V.R.	M.S.	V.R.	M.S.	V.R.	M.S.	V.R.
Varieties . .	72	63·45	1·68**	49·07	1·40*	5·827	12·64**	0·4283	4·21**
Error . .	512	37·60	..	34·95	..	0·461	..	0·1019	..

** Significant at 1 per cent
* ,, ,, 5 ,, ,,
$N_1 = 50$ and $N_2 = 400$ P = 1·38 for 5 per cent.
P = 1·57 for 1 per cent.

The values were then converted into logarithms and variances and covariances between pairs of different characters were obtained. The two covariance matrices of the varietal and error line in the analysis of variance and covariance are given in Tables IX and X respectively.

TABLE IX

The values of tij

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm. 4
Tillers	1	0·01397	0·01278	—0·00168	—0·00100
Ears	2	..	0·01291	—0·00134	0·00082
No. of grains per ear	3	..	..	·00688	—0·00055
Weight of 100 grains in gm.	4	..	..	..	0·00368

TABLE X

The value of cij

i	j	Tillers 1	Ears 2	No. of grains per ear 3	Weight of 100 grains in gm 4
Tillers	1	0·00966	0·00955	0·00079	—0·00004
Ears	2	..	0·01107	0·00098	—0·00026
No. of grains per ear	3	..	..	0·00392	0·00009
Weight of 100 grains in gm.	4	..	..	..	0·00209

The details of the calculations involved in obtaining a discriminant function need not be repeated here as they have been fully described before. The solution of the equations gave the following values of b, the coefficients of the discriminant formula :

Characters	Coefficients	Numerical values
Tillers	b^1	2·2335
Ears	b^2	2·2658
No. of grains per ear	b^3	0·2639
Weight of 100 grains in gm.	b^4	2·0064

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The discriminant formula therefore reads :

$$Y = 2{\cdot}2355\ {}_1X - 2{\cdot}2658X_2 + 0{\cdot}2639X_3 + 2{\cdot}0064X_4$$

In this function, the coefficients for number of tillers and weight of 100 grains are positive and high, showing that as these two characters have the highest genetic correlation with yield, selection based on high tiller number and high grain weight will increase the yield of the progenies. The number of ears, as shown before, is negatively correlated with yield. The coefficient for number of grains per ear is positive but has a small value.

The discriminant function formula based on selections within the local sample of Malvi wheat is thus very similar to that derived from the wider variations between *durum* samples from different parts of the country, except for grain number per ear. We may thus formulate the general rule that selection for higher yield in *durum* wheat should primarily be made on the basis of higher number of tillers and higher grain weight.

The expectation of genetic improvement through the use of discriminant function is about 10 per cent over ordinary selection. This means that in samples of low variability also the use of discriminant function is found to be valuable.

Discussion

The primary object of the plant breeder is the production of high yielding varieties. Since yield is composed of number of ears per plant, number of grains per ear and weight of single grain, selection for high yield would mean selection for higher number of ears, higher number of grains per ear and higher grain weight. The breeder, therefore, requires some objective guidance for his selection by which he can exploit the part played by each component in building up the yield.

In the past, various ratios such as the migration coefficient or the survival rate of tillers, were used for judging the yielding capacity of a plant, since such ratios were found to be more stable, that is, had greater freedom from environmental fluctuations than the component characters which are highly affected by environment. But these ratios are of arbitrary nature and are not based on any theoretical considerations. Engledow and Wadham [1923] found that though the migration coefficient appeared to hold some promise as an index of yielding power of single plants, it appeared unsuited to the complete displacement of eye judgment because of the labour it involved. Bell [1937] and Hunter [1938] found high ear survival as the most important index of yield in Barley, but Stephens' results on oats [1942] are in direct variance with Bell and Hunters' conclusions. All these conclusions indicate that these ratios are not sound guides to judge the yielding capacity of plants. The discriminant function method for making selection in plants is more rational as the function not only shows the extent to which each character is genetically related to yield but if the samples are scored by means of this function, the sum total of the linear function of characters gives a value highly correlated with the genotypic yield potentiality of the sample from a given population.

The discriminant function formula for evaluating the yielding power of *durum* wheats are worked out on samples collected from two different sources showing varying amount of variability. These sources are the samples of local and improved strains of *durum* wheat from Bengal, Central Provinces, Hyderabad Deccan, Bombay and Central India States, and the bulk of selected progenies from Malvi local.

The results obtained indicate that a general rule for selection in *durum* wheat cannot be dictated as for such studies a larger number of samples should have been included, but the formulae obtained so far are more or less similar and the results can be stated as follows : (1) discriminant function formula obtained from provincial *durums* shows that tiller number and grain weight have genetic corelation with yield and should only be considered while making selection for high yield, (ii) tiller number and straw weight are highly ccrrelated and to a lesser extent grain weight with yield of bulks of selected progenies from Malvi local. All these formulae therefore stress the importance of tiller number and grain weight as the basis of selection for improving the yield of *durum* wheats. Smith [1937] working with *vulgare* wheats also found that ear number and grain weight were highly correlated with yield.

Since the discriminant function gives values highly correlated with the genetic values of the samples of a given population, the expectation of improvement through discriminant function is always higher than by ordinary selection in which the samples are selected on the basis of their observed values taking them to be the true expression of the genotypic values of these samples, as will be seen from the results of provincial *durums* which show an improvement by selection with the help of discriminant function of about 16 per cent higher than ordinary selection. The efficiency of discriminant function is still higher when used for making selection in samples which show low genetic variability among themselves. For example, in bulks of selected progenies the expectation of improvement is about 10 per cent higher than ordinary selection.

These results illustrate how an objective method of selection can be formulated for improving the yield and other quantities of wheat.

Considering the similarity of conclusions from these trials it can be stated with confidence that selection in *durum* wheats can be based on characters like tiller number and grain weight.

SUMMARY

In order to work out a discriminant function for selection in *durum* wheats, two experiments were laid out, one in 1940-41 and another in 1941-42. The second experiment consisted of samples of local and improved strains collected from Indian States and British India provinces. These were grown in five randomized blocks. Twenty plants selected at random were labelled in each plot for observations which were harvested individually. Observations recorded on random plants were analyzed statistically. The results show that the differences between the varieties for different characters are highly significant. Correlation coefficients were determined between pairs of different characters for varieties and also for error.

The data for each character were converted into logarithms and variances and covariances between all pairs of characters were obtained. With the help of these variances and covariances a discriminant function formula is obtained which shows that tiller number and grain weight are highly correlated with the genetic yield of the varieties, and should be the basis for selection for higher yield in provincial *durums*.

The other experiment (carried out in 1940-41) consisted of seventy-two single ear bulks selected from a local *durum* and compared with local *durum* in a Symmetrical Incomplete Randomized Block layout. Twelve per cent of the average number of plants per plot were sampled out for various observations. These observations were analyzed statistically, and the results indicate high significant differences between the progeny bulks in all characters. The values were converted into logarithms and coefficients of discriminant formula were obtained. This function is similar to the one obtained from Provincial *durum* except for grain number per ear which is high and negative in provincial *durums*.

The expectation of genetic improvement is also calculated in both experiments. In provincial *durums*, if all characters are included, the expected genetic advance is 16 per cent higher than ordinary selection, and when tillers are omitted, it is still higher by 5 per cent. In single ear bulks, the expected genetic advance is about 10 per cent. These percentages stress the efficiency of selection by means of discriminant function.

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STUDIES IN PUNJAB MOTH (*Phaseolus aconitifolius*)

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(With ten text figures)

Moth (*Phaseolus aconitifolius*) is an important legume of semi-arid regions. Piper [1937] has reported that this crop is a native of India, where it is grown principally as a pulse crop; but large areas are put under it as a forage crop both in the irrigated and *barani* (rain fed) areas of the province; and as such it is usually grown either alone or in mixture with non-legumes like *jowar* (*Sorghum vulgare*) *bajra* (*Pennisetum typhoideum*) *sesamum* (*Sesamum orientale*) and some times with cotton. Its use as a pulse, however, is limited to the south-east Punjab alone.

According to the acreage under crops grown exclusively for forage, collected through the Revenue Department in 1937, *moth* occupied an area of 250,000 acres in the Punjab. This acreage should not in any way be taken to mean that *moth* is a crop of lesser importance as compared to other forage crops, as it is highly drought resistant and is able to produce comparatively high tonnage of green fodder under poor-land conditions with limited supply of irrigation water or scanty rainfall.

Inspite of the fact that the crop has been cultivated in the province for a very long time, there is a great dearth of superior and high yielding varieties. Efforts were, therefore, made to find out some variety or varieties with a view to improving the existing situation.

A large number of investigations on both European and American varieties of field beans have been reported, but up to the present time, none has dealt with the species of *Phaseolus* and the varieties of *Phaseolus aconitifolius* grown for forage or seed. The *moth* bean is grown under a very wide range of climates from the hills of Kangra Valley to the dry tracts of Dera Ghazi Khan, but its chief importance is in the dry tracts. Since the range of climate between these two extremes is very wide, it follows that varieties grown in one part may not always be adapted to the other. The choice of a variety adapted to local conditions affects directly the yield and economic utility of the crop; hence it is absolutely essential that a variety suited to a particular locality should only be selected. However, in order to be able to make this choice, the identity of types and varieties must be established with certainty. It is, therefore, necessary that local *moths* should be classified so that their identity can be established. It is the purpose of this study, (I) to find out a practical basis of classification of field varieties of *moth*; (II) to construct a key based on these characters which are stable under varying climatic conditions; (III) to describe the types grown at the Fodder Research Station, Sirsa; and (IV) to establish one or more types superior to others under the climatic conditions prevailing in the province.

Review of literature

Steinmetz and Arny [1932] reviewed the literature on the subject and stated that Von Martens published his second revised classification of garden beans in 1869, but he made no distinction between garden and field beans. He classified *Phaseolus vulgaris* into seven species according to the shape of seed, and based his secondary division on the colour of the seed.

Irish [1901] described almost all varieties from cultures grown at the Missourie Botanical Garden, on the basis of form and colour of seed, and further used plant and immature pod characters.

It is, however, impractical to use immature pod characters for classification, because pods as such cannot be stored. But seed, pod and type of plant provide a reasonable basis of comparison and identification.

Tracy described American varieties of garden beans in 1907, basing his classification on the habit of the plant and character of green pod. But the distinction will become more apparent if comparison is instituted through the ripe pods. Tracy refers to twelve varieties of field beans.

The description of American varieties by Jarvis [1908] is based on colour, form and size of seed. He grouped varieties according to the type of plant and the character of the pods and refers to 21 varieties.

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Freeman [1921] described six native field varieties of *Phaseolus vulgaris*, while Hendry [1918] described 16 varieties of field beans adapted to California.

Though classification is of great value to growers and seed producers, its usefulness is very limited.

Materials and methods

It was in the year 1932-33 that a collection of samples of *moth* bean was started. Seed from different *moth* growing areas of the province was secured through the local staff of the Agricultural Department, growers and some Experimental Stations. Efforts were made to obtain seed from all the main *moth* growing areas in the Punjab. The growing of these samples began in 1933 and intensive work with a view to isolate definite types began when the crop was harvested in 1936-37.

To start with *moth* samples were planted in rows 2 ft. apart, but later on were planted 3 ft. apart keeping a distance of about 6 in. from plant to plant in order to study the variants in each sample. Typical and non-typical plants were selected and their seed was grown in progeny rows for observation. The rows showing uniformity and the best performance record were selected and multiplied.

In order to keep the variety pure and to safeguard the effect of crossing, if any, the plants which showed some variation from the selected types were rogued out.

The samples were studied for a period of four years from 1933-34 to 1936-37 at the Fodder Research Station, Sirsa, under irrigation, but under severely hot and dry climatic conditions of the tract.

Classification and description

Based on the character of the mature plant

The observations reported herein, are based on the following characters of the full grown plants at the Fodder Research Station, Sirsa :

(i) *Habit of growth*.—In habit of growth *moth* beans may be classified into semi-erect, semi-spreading and spreading, but the range is not very distinct in the mature plants. Usually *moth* has indeterminate habit of growth and as such this character has very limited applicability in classification.

(ii) *Shape of leaves and size of lobes*.—The shape of leaves is a character of utmost importance in *moth*. In the present study the varieties consisted of two main divisions (*a*) broad lobed and (*b*) narrow lobed. The lobes of the former are broad with 3-5 lobes and serrated margins, and those of the latter are palmate having long and narrow finger like lobes. The use of absolute measurements in the description of either broad or narrow lobes, however, appears to be impracticable, because of the wide variations in the size of leaf on a single plant.

(iii) *Time of maturity*.—Time of maturity is of considerable importance, for the length of growing season determines to a great extent the yield of green stuff. It is also of great importance in identifying varieties, which are otherwise similar in their habit of growth and colour of seed. The narrow and broad lobed varieties differ in the time of their maturity—the narrow types ripening approximately one to two weeks earlier than the broad lobed strains.

(iv) *Pod characters*.—Unlike the variation in vegetative parts due to environment, character of the pod is not influenced to any great extent, and is, therefore, more useful in the distinguishing of varieties.

(*a*) *Colour of pod*.—The characteristic colour is developed as soon as the pods approach maturity. Type No. 1 shows straw colour, while No. 2 has smoky colour. Colour in pods is described as it is found to be at the time of maturity.

(*b*) *Length of pod*.—The length of pods has been used by many writers in the description of varieties. Tracy [1907] gives approximate length, breadth and thickness. In the present description length of mature dry pod was measured.

(v) *Dry seed character*.—The mature and dry seeds were used exclusively for classification of the American varieties of beans by Jarvis [1908]. The seeds have invariably been used for the description of varieties by all workers and the descriptions reported are in accord with that practice.

(*a*) *Size*.—The size of dry seeds as reported in this discussion is expressed in two sizes, medium and bold.

(*b*) *Colour.*—Von Martens and others have used the colour of seed for distinguishing varieties. The colour of seed has been recognized by all writers, but Freeman [1921] cited a standard colour chart. *Moth* beans have been arranged in this description into two main groups, namely those with single colour seed coats and those with patterned seed coats. Shaw and Norton [1918] have pointed out that there is no consistent correlation between seed coat colour and colour of flowers; this fact agrees with the findings of this study of *moth* beans.

Summary of characters useful in classification of *moth* beans

The following characters may be used in classifying varieties of *moth* beans :

(*a*) Shape of leaves and size of lobes.

(*b*) Habit of growth of the plant, *viz.*, semi-erect or spreading.

(*c*) Time of maturity.

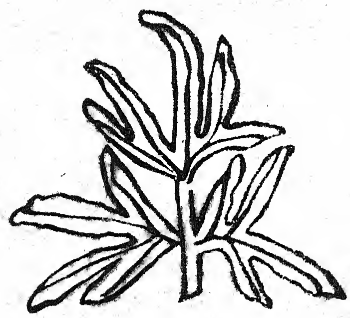
(*d*) Pod colour and length.

(*e*) Dry seed characters, colour and size of the dry seed.

The present study revealed that the *moth* beans could be broadly classified into two main divisions. In one case the leaves are more or less palmate with long and narrow finger like lobes, while in the other the leaves are much broader with 3-5 lobes and serrated margins.

Description of varieties of *moth* beans

Samples of seeds from the various sources were first grown under the name of the place of origin. The names were retained for one year, but as the samples were not true to any known variety description, they were substituted by selection numbers. Later these numbers were replaced by type numbers after the material had been classified and described. The description of the narrow and broad lobed types, shown in figs 1 to 10 is given below :



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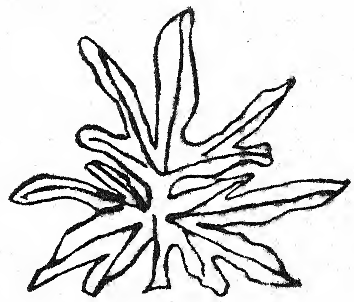

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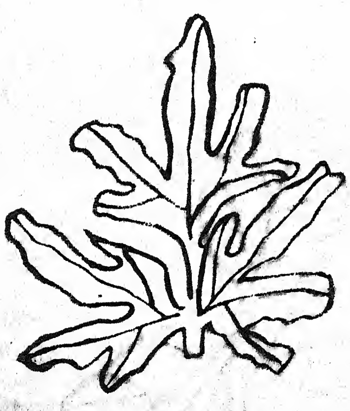

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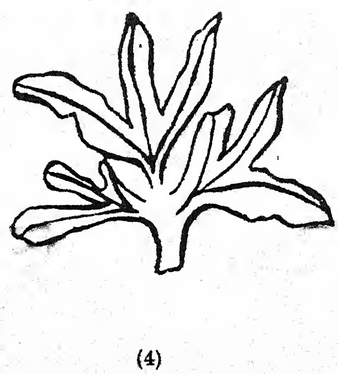

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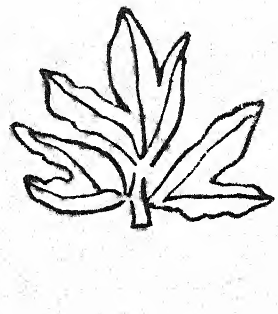


(5)

Narrow lobed types

Type No. 1.—Plants semi-spreading; leaves dark green, lobes very narrow, central finger of the lobe 3·9 cm. long. ·66 cm. broad; mature pods straw coloured, 4·0 cm. long; seeds per pod 6.6, medium brown, 100 grain weight 1·90 gm.

Type No. 2.—Plants highly spreading; leaves dark green, lobes very narrow, central finger of the lobe 3·8 cm. long., 0·52 cm. broad; mature pods smoky coloured, 3·63 cm. long, seeds per pod 6·9, medium, colour buff with black pattern, 100 grain weight 2·61 gm.

Type No. 3.—Plants semi-errect to semi-spreading; leaves dark green, lobes narrow, central finger of lobe 5·52 cm. long, 1·16 cm. broad; mature pods smoky coloured, 3·73 cm. long, seeds per pod 6·1, medium light brown. 100 grain weight 2·23 gm. Prolific and fairly disease and drought resistant.

Type No. 4.—Plants spreading; leaves dark green, lobes narrow, central finger of the lobe 5·24 cm. long, 1·02 cm. broad; mature pods smoky, 3·63 cm. long, seeds per pod 6·4, medium, greyish brown. 100 grain weight 2·07 gm.

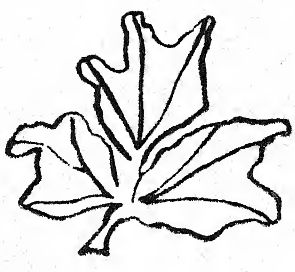
Type No. 5.—Plants spreading; leaves dark green, lobes narrow, central finger of the lobe 4·45 cm. long, 1·1 cm. broad; mature pods smoky, 3·61 cm. long, seeds 6·3 per pod, medium, colour buff with black pattern, 100 grain weight 1·95 gm.

Broad lobed types

Type No. 6.—Plants semi-erect; leaves green, lobes broad, central lobe 4·62 cm. long and 3·28 cm. broad; mature pod straw coloured, 3·77 cm. long, seeds 6·3 per pod, bold brown; 100 grain weight 2·15 gm.

Type No. 7.—Plants semi-erect; leaves green, lobes broad, central lobe 4·9 cm. long, 4·6 broad; mature pod light smoky 4·11 cm. long, seeds per pod 6·2, medium, light brown. 100 grain weight 2·35 gm.

Type No. 8.—Plants semi-erect; leaves green, lobes broad, central lobe 4·56 cm. long, 3·1 cm. broad; mature pod smoky, 4·11 cm. long, seeds 7·1 per pod, bold, grey, 100 grain weight 2·15 gm.



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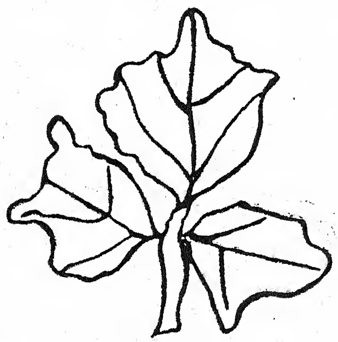

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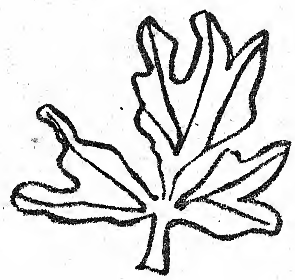

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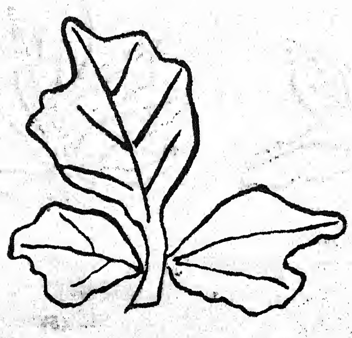

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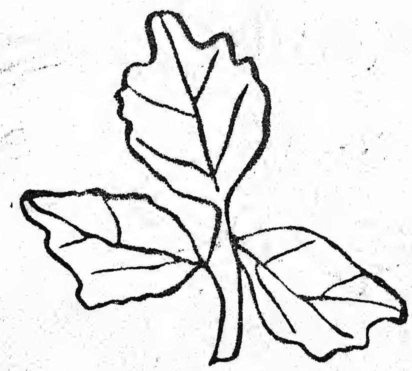

(10)

Type No. 9.—Plants semi-erect ; leaves green, lobes broad, central lobe 5·02 cm. long, 3·46 cm. broad ; mature pods light smoky, 3·81 cm. long ; seeds per pod 6·3, medium, buff with black pattern, 100 grain weight 2·30 gm.

Type No. 10.—Plants semi-erect to semi-spreading ; leaves green, central lobe 4·92 cm. long, 4·18 cm. broad ; mature pods light smoky, 3·61 cm. long, seeds per pod 5·9, bold, brown, 100 grain weight 2·31 grams.

From a large collection of *moth* samples it was possible to isolate ten distinct types, which have been described above. Each type has been given a number for identification.

Forage yield data have been secured from six promising types out of the ten mentioned above. These data have not been used in the classification, but serve to indicate the value of the varieties under different environmental conditions prevailing in the Punjab.

Along with the study of botanical characters useful for classification, some of the promising types were grown to study their forage value. Since the primary objective of the work was to make available to the cultivators high yielding varieties for forage, results of some of the agronomic studies of six types are reported. To start with, the experiment to compare the forage yielding capacity of these six types was conducted on a field scale at the Fodder Research Station, Sirsa, in randomized plots in 1935-36, and repeated in 1936-37. Later on trials were extended to other Departmental Experimental Stations in order to study their behaviour under different sets of environmental conditions at Montgomery, Hansi, Jullundur, Multan, and Lyallpur under irrigation, and at Rawalpindi and Gurdaspur under *barani* (rain fed) conditions. These trials, which were continued for a period of five years, enabled a detailed study of the influence of variation of environments at different stations within the same year, and at each station in different years.

The sowings at these stations each year were carried out at the usual sowing time, and the crop with a few exceptions made satisfactory growth. The results obtained were very conclusive and enabled a selection of a type, which was approved for cultivation in the Punjab.

The average yields of green fodder per acre, based on the results of these trials at different Agricultural Experimental Stations, are given in Table I.

TABLE I

Yields of green fodder per acre in maunds of the moth *types at the various Agricultural Stations*

1. *Fodder Research Station, Sirsa*

Yield of green fodder per acre in mds.

Year	Types						Local	Significance	Critical difference	
	2	3	4	7	9	10			at 1 per cent	at 5 per cent
1935-36	199	324	304	275	240	..	..	Significant	33	54
1936-37	358	440	377	380	358	299	..	,,	..	67
1937-38	350	458	414	392	384	348	392	,,		
1938-39	342	400	392	368	384	368	322	,,		
1939-40	214	310	292	280	286	290	232	,,		
1940-41	290	360	358	298	284	306	332	,,		
1941-42	233	333	319	321	321	327	288	,,		
Total	1,753	2,625	2,476	2,214	2,257	1,938	1,566			
Average	292	375	353	316	322	323	312			
2. *Montgomery Agricultural Station*										
1937-38	230	305	358	286	271	252	274	Significant	24·9	18·5
1938-39	119	179	187	212	170	149	144	,,	40·3	29·9
1939-40	116	226	118	232	134	176	140	,,	48·0	35·0
1940-41	83	188	161	131	102	154	120	,,	33·7	24·8
1941-42	..	225	185	174	169	188	170	,,	23·9	17·5
Total	548	1,123	1,009	1,035	846	919	858			
Average	137	281	252	259	211	229	214			

TABLE I—*contd.*

Yields of green fodder per acre in maunds of the moth *types at the various Agricultural Stations* – contd.

Year	Types						Local	Significance	Critical difference	
	2	3	4	7	9	10			at 1 per cent	at 5 per cent
3. *Honsi Agricultural Station*										
1937-38	96	180	150	127	114	111	110	Significant	26·3	19·5
1938-39	254	298	280	292	261	292	271	,,	9·3	6·9
1939-40	..	..	..	..	..	..	..			
1940-41	221	214	230	221	185	179	198	Insignificant	8·2	6·1
1941-42	278	336	285	287	254	309	296			
Total	849	1,028	945	927	814	891	875			
Average	212	257	236	232	203	223	219			
4. *Agricultural Station, Jullundur*										
1937-38	71	90	90	113	109	664	94	Significant	33·0	25·0
1938-39	52	85	76	86	67	65	70	,,	32·0	24·0
1939-40	88	107	123	131	138	141	96	,,	8·2	6·1
1940-41	142	151	169	146	155	150	153	Insignificant	10·7	7·8
1941-42	65	80	64	69	..	..	71			
Total	418	513	522	545	469	420	484			
Average	83	102	104	109	117	105	97			
5. *Agricultural Station, Multan*										
1937-38	112	157	135	128	127	113	101	Insignificant		
1938-39	..	..	..	..	..	..	..			
1939-40	..	..	..	..	..	..	..			
1940-41	113	168	151	134	115	139	142			
1941-42	198	249	242	212	204	250	194			
Total	423	565	528	474	446	502	442			
Average	141	188	176	158	148	161	144			
6. *Lyallpur Agricultural Station*										
1937-38	99	118	117	132	130	105	80	Significant	34·0	25·0
7. *Gurdaspur Agricultural Station*										
1940-41	200	203	215	207	216	209	215	Insignificant	27·5	20·4
8. *Rawalpindi Agricultural Station*										
1938-39	62	83	68	71	63	65	63	Significant		
1939-40	71	93	81	102	84	83	66	Insignificant		
1940-41	61	61	79	74	68	67	61	Significant		
1941-42	102	126	117	103	95	105	106	Insignificant		
Total	296	363	345	350	310	320	296			
Average	74	91	86	87	77	80	74			

Discussion

Yields of green fodder per acre of the six types 2, 3, 4, 7, 9 and 10 were fairly satisfactory at the Fodder Research Station, Sirsa, under irrigation throughout the period of seven years, and significant differences were observed in the performance of these varieties. Taking the data year by year, it is apparent that Type No. 3, with narrow lobes and brown seeds, out-yielded all other types throughout the period of the experiment, and yielded, on an average of seven years, 375 maunds of green fodder per acre. Type No. 4, another narrow lobed type with brown seed, was the second best, yielding on the average, over the same period, 353 maunds of green fodder per acre.

The performance of these types at the Montgomery Agricultural Station under irrigation was quite satisfactory, and the results of the comparative tests were highly significant throughout. Type Nos. 3, 4 and 7 yielded higher than other types and the local. On the average of five years, Type No. 3 was at the top of the list, giving an outturn of 281 maunds per acre. It was closely followed by Type Nos. 4 and 7 which yielded 259 maunds and 251 maunds of green fodder per acre respectively.

The results of the Hansi Agricultural Station, under irrigation over a period of four years, corroborated those obtained at Sirsa and Montgomery. Type No. 3 out-yielded all others, giving an average outturn of 257 maunds of green fodder per acre. It was followed closely by Type Nos. 4 and 7, which gave 236 and 232 maunds of green fodder per acre respectively.

On the average of five years, the yield of green fodder of all the types, except Type No. 2, were higher than the local at Jullundur, but differences among them were not marked. Type No. 9, a broad lobed type, gave the highest yield, followed closely by Type No. 7 and others. It may be inferred that no variety of *moth* is likely to give very high yields, Jullundur being situated in that part of the Punjab, where there is comparatively high rainfall and high humidity, a climate which is not very suitable for this crop.

Yields at the Multan Agricultural Station are not very encouraging; but keeping in view the nature of the soil, which is mostly alkaline, and limited availability of irrigation water, because irrigation is carried on by wells (now farm area has been irrigated through a canal), and very low rainfall and low humidity, outturns of green fodder appear fairly satisfactory. On the average of three years (as trials could not be arranged for the two years, 1938-40), Type No. 3 has out-yielded all other types and the local by a fairly wide margin ; Type No. 4 is a close second yielding 176 maunds per acre.

The test was conducted for one year at the Lyallpur Agricultural Station, and during that year only Type No. 7 significantly out-yielded the local. The yields on the whole were very low as the experiment was conducted on a very light soil.

Gurdaspur, which represents another humid tract of the Punjab, is also not very suitable for the growth of the *moth* crop. Here yields obtained from various types and the local were almost equal.

Comparative trials of *moth* types at the Rawalpindi Agricultural Station under *barani* conditions can hardly be expected to give very high yields of green fodder. The results of four years' experiments at this station showed the superiority of Type No. 3, followed closely by Type Nos. 4 and 7.

The results of the above trials, carried out for a period of about half a dozen years, show fairly conclusively the superiority of Type No. 3 over the local as well as other types with which it was compared. The yields have been fluctuating from year to year at the same station and were markedly at variance at the different stations within the same year. It is evident that environmental conditions vary from year to year at the same station, and from one station to another, which is shown by the yields of Type No. 3 (Table II, *see* next page) during these years at the same station in different years, as well as at different stations during the same year.

Often conclusions from varietal experiments, based on the results of a single season, are likely to be highly misleading. Data, which are obtained from a wide range of ecological conditions obtaining from year to year at the different stations, and in different years at the same station, show conclusively that Type No. 3 is a variety which can do better than other types in the arid areas of the Punjab. Accordingly it was recommended and placed on the list of approved seeds of the

Department of Agriculture, Punjab. Type Nos. 4 and 7 follow Type No. 3 closely, but further breeding work on the crop is likely to yield much superior strains than these types and Type No. 3.

TABLE II

Yields of green fodder per acre of Type No. 3 in maunds

Year	Stations							
	Montgomery	Sirsa	Hansi	Jullundur	Multan	Lyallpur	Gurdaspur	Rawalpindi
1935-36	..	324	..	..	..	..	..	..
1936-37	..	440	..	..	..	..	..	..
1937-38	305	458	180	90	157	118	..	..
1938-39	179	400	298	85	..	..	..	83
1939-40	226	310	..	107	..	..	..	93
1940-41	188	360	214	151	168	..	203	61
1941-42	225	333	336	80	240	..	..	126

SUMMARY

(1) A large collection of *moth* samples was studied for a period of four years, and on the basis of the stable characters, the material was classified.

(2) The Punjab *moth* can broadly be classified into two main divisions, *viz.* narrow lobed and broad lobed.

(3) In all ten distinct types were isolated on the basis of the habit of the plant, size of lobe, colour of mature pod, length of the pod, and colour and size of the seed.

(4) Out of the narrow and broad lobed ten types, six of which appeared promising for forage, were selected and grown at the Fodder Research Station, Sirsa, and later on at other Agricultural Experiments Stations in order to study the influence of varying environments on the fodder yielding capacity of each type.

(5) The yields of green fodder, obtained at Sirsa and other stations, showed conclusively the superiority of No. 3, a narrow lobed type with medium brown seed.

(6) On the basis of its performance, it has been placed on the list of approved seeds of the Department.

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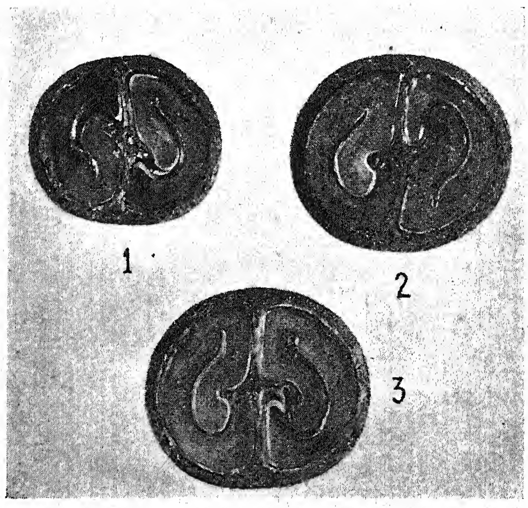
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3

THE ORIENTATION OF THE SEEDS IN SPECIES OF COFFEA LINN. IN MYSORE

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(Received for publication on 18 November 1946)

(with plate XVIII)

DURING the investigation of black bean in coffee [Venkatarayan, 1938] certain peculiarities in the orientation of the beans in coffee fruits were noticed. On cutting fruits transversely and examining always the basal half, the appearance of the cleft in the endosperm of the two beans together with their funicles and placentae, is quite characteristic. In a large number of cases it resembles roughly the letter U (Plate XVIII, fig. 3), the two beans being quite symmetrically arranged. The cleft on one side of the fruit is turned left, while the endosperm itself is turned towords the right, and on the other side the cleft is turned right, and the endosperm left. The former may be considered to be a right-handed seed, and the latter left-handed. In some other fruits the appearance of the clefts is like a rounded off Z (Plate XVIII, fig. 1), while in others it is like the letter S (Plate XVIII, fig. 2).In the Z-type since both clefts are turned left, both the seeds are right-handed, and in the S-type, conversely both the seeds are left-handed.

The species of *Coffea* commonly grown in Mysore are *Coffea arabica* Linn., *C. liberica* Hiern. and *C. Laurentii* Wildem. (*C. robusta* L. Linden). *C. arabica* fruits for examination were obtained in 1937 from a private estate, and in 1938, fruits of all the three species on their branches were obtained from the Mysore Government Coffee Experiment Station, Balehonnur. The occurrence of round beans or peaberry in a fruit spoils the count, and hence these were excluded.

Table I shows the results of the examination :

TABLE I

The distribution of the different types of fruits in Coffea *spp.*

—	U-type		Z-type		S-type		Total three types	Peaberry		Total	
	No.	percentage excluding peaberry	No.	percentage excluding pea berry.	No.	percentage excluding peaberry		No.	percentage of total	Fruits	Twigs
C. arabica—1937 . .	134	51	76	29	54	20	264	40	13	304	12
C. arabica—1938 . .	250	48	115	22	153	30	518	144	22	662	12
C. liberica—1938 . .	134	35	97	25	155	40	386	232	38	618	18
C. robusta—1938 . .	335	37	261	29	305	34	901	312	25	1213	6

It is seen that the U-type arrangement predominates except in *C. liberica*, where owing perhaps to the undue preponderance of peaberry, the-behaviour is anomalous. Of the other two types sometimes one predominates and sometimes the other. In the same cluster in one and the same twig may be found all the three types of arrangement. In all of them the radicle in the seeds is inferior with the micropyle directed downwards and outwards.

Gandrup [1923] in a preliminary count of 11592 beans, mostly of *C. robusta*, found 6156 left-handed and 5436 right-handed or 53·11 per cent left and 46·89 per cent right. In a more detailed examination of a number of berries of *C. robusta* he found U-type berries to vary from 36·84 per cent to 44·79 per cent, while in *C. excelsa* it was 49·68 per cent and in *C. liberica* 44·73 per cent. He had no occasion to examine *C. arabica*. He designates the U-type, antidrom berries, the Z-type, homodrom right, and the S-type, homodrom left. Antidrom is a term used for individuals of the same species displaying right and left hand torsion. In homodrom, the torsion is in the same direction. But variations of the arrangements occur now and then, and it becomes difficult to determine their nature without a careful examination with a lens. Sometimes a secondary fold develops from the endosperm folds and keeps pace with the original fold, thus making it difficult to distinguish between the original and secondary folds. Gandrup [1923] found this variation to occur to the extent of 10 to 18·36 per cent and suggests that this might have some relation to the hybrid nature of such trees. Gandrup [1923] mentions, as a result of a germination study, that the homodrom

left beans have a comparatively poorer percentage of germination than the homodrom right or antidrom beans. No experiments have been conducted here on these lines.

According to Gandrup [1923], Hanausek [1895] working with *C. arabica* did not find as a rule symmetrically developed seeds in the same fruit, but only similarly developed (gleichsinnig) seeds, and only unusually did he find in a fruit a right and a left seed. Gandrup [1923] says that Froehner [1898] found the seeds to develop symmetrically, and also that according to Froehner [1898] there is a possible relation between this and the symmetry in the inflorescence. Gandrup [1923] was not able to confirm this, and suggests that an anatomical study be made to trace any relation between the position of the endosperm folds and the position of the contorted corolla lobes.

Schumann [1891] figures the U-type arrangement for *C. liberica* Bull. Zimmermann [1928], after Marchand, figures the same arrangement for *C. arabica* Linn. Zippel and Thome [1899] figure the U-type arrangement for *C. arabica.* According to Gandrup [1923], von Wettstein in his handbook figures a *liberica* fruit wherein both beans are bent to the right (Z-type or homodrom right) Ukers [1935] after Tschirch and Oesterle, figures the Z-type of arrangement of seeds for *C. arabica.* According to von Faber [1911] the curvature of the ovule is mostly not sympathetic (nicht gleichsinnig) ; by this he means presumably that the berries are of the U-type or symmetrical, but immediately he says that often this is the case, meaning sympathetic or homodrom. This is opposed to Hanausek's view.

The reason for the curvature of the ovule and the presence of the cleft in the endosperm, according to von Faber [1911], is that the locule, at first circular, grows in the tangential direction, becoming radially flattened. Possibly to economize space, the ovule turns close to a side of the locule and when this side is filled up, it bends down the other side. When the locule has reached its definite size and shape, the ovule is forced to bend itself once more to find further space. This it does at the end opposite to the insertion point of the funicle and pushes in between the septum and funicle. von Faber [1911] believes that this growth in length takes place at the distal portion of the endosperm. Gandrup [1923] is, however, of the view that it takes place at the basal portion. This difference of opinion is not of much consequence, since the result is the same. But why in the same plant there should be the three or possibly four different kinds of orientation of the seeds is not clear. Gandrup [1923] was probably right when he connected this with the hybrid character of the plants in the field. The writer's own [Venkatarayan, 1938] deductions in regard to black bean in coffea, point to the conclusion that there are possibly a number of hybrid plants in any estate. But this hypothesis requires experimental confirmation.

Summary

In this paper, the orientation of the seeds in *Coffea arabica* Linn., *C. liberica* Hiern., and *C. Laurentii* Wildem. (*C. robusta* L. Linden) in Mysore is described. If fruits are cut transversely, and the basal half examined (each seed viewed from the ventral side) the appearance of the cleft in the endosperm, the funicles and placentae is characteristic. In the majority of fruits the appearance suggests the letter U, the two seeds being symmetrically arranged. In other fruits, the appearance of the clefts resembles a rounded off Z and in yet others the clefts resemble the letter S. There are also some abnormalities associated with this arrangement.

The U-type fruits are antidrom, the Z-type fruits are homodrom right, and the S-type, homodrom left.

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FIELD-STUDIES ON SUGARCANE BLACK BUG (*MACROPES-EXCAVATUS* DIST.) IN THE PUNJAB

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(Received for publication on 21 November 1944*)

BLACK BUG (*Macropes excavatus* Dist.) is one of the destructive pests of sugarcane in the Punjab. According to Rahman and Ram Nath [1939], the first report of its occurrence as a serious pest of sugarcane in the Kangra valley was received in July, 1930; later reports were from Bhalwal (Shahpur District) Gurdaspur, Kabirwala, (Multan district), Lyallpur and Sonepat (Rohtak district). Since then, it has been found to be widely distributed in the districts of Karnal, Ambala, Ludhiana, Jullundar, Hoshiarpur, Ferozepore, Amritsar, Lahore, Gujranwala and Jhang. The nature of damage caused by this pest has been described by Rahman and Dalbir Singh [1943]. During July 1943, *Macropes excavatus* Dist. appeared in an outbreak form at Karnal and the different varieties of sugarcane appeared to have different intensities of attack. The present paper embodies the results of the investigation carried out on its behaviour and population during 1943-44.

METHOD AND MATERIAL

The sugarcane black bug multiplied in large numbers at the District, Agricultural Farm, Karnal during July-August, 1943, in the five varieties of sugarcane, *viz.*, Co.L.5, Co.L.7, Co.312, Co.395 and Co.421, which had been planted in replicated plots. In each variety, population of the pest on every part of the plant was recorded during the second half of August when the pest was found both in the nymphal and adult stages. For population studies, 300-500 canes, taken at random, from each variety, were examined. The insects were found inside all the loosely attached leaf-sheaths and in the top-whorl. By August, every cane shoot had two to ten partially separated leaf-sheaths and almost all of these were harbouring insects. Separate records of the number of insects (both adults and nymphs) found inside all the leaf-sheaths and in the top-whorl of each sugarcane shoot were obtained. Observations on similar lines were also recorded during the fourth week of November, 1943, when the pest was found exclusively in the adult stage and a large number of leaves, up to 21 in certain cases, had dried and separated from the cane stem. These observations were repeated during the last week of April, 1944 when the pest was met with only in the nymphal stage. The leaf-sheaths were then tightly fitting to the main stem and as such most of the insects were found in the top-whorl. Thus observations on the behaviour and population of the pest in the fields were recorded during all the phases of its activity and life-history.

INTENSITY OF ATTACK IN DIFFERENT VARIETIES

The data collected on the above lines were statistically analyzed. The susceptibility of the five varieties of sugarcane, under consideration, can be determined in two ways, namely, the percentage of infested shoots and population of black bug per shoot in each variety. The number of black bugs per infested leaf-sheath varied from 1-4, 1-40 and 1-9 during April, August and November respectively. The total population of the insects per infested shoot during April, August and November ranged from 1-21, 1-92 and 1-32 respectively. The percentage of infested cane-shoots and the average population of pest in different varieties, recorded at different times, are given in Table I.

*Subsequently received in a revised form on 8 July 1947

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TABLE I

The average population of the pest per shoot

Varieties				Percentage of infested cane.		
	April	August	November	April	August	November
Co.421	5·32	7·46	12·93	99·3	92·6	99·3
Co.L.5	5·17	7·08	12·6	96·3	81·2	100·0
Co.L.7	4·98	5·13	12·8	98·0	70·9	100·0
Co.395	4·35	3·82	8·32	95·6	72·8	93·3
Co.312	5·17	3·45	11·71	99·3	81·9	99·3

It will be observed from Table I that during April when the crop was young and the sugarcane black bug had just resumed activity after wintering, there was hardly any difference in its population in the varieties under consideration, and about the same percentage of shoots was found infested in all the varieties. During August when the pest was most active, it exhibited differential behaviour towards different varieties. The figures in Table I reveal that during August the average population of the pest per cane shoot as well as the percentage of infested shoots, were different in different varieties. Figures are the highest in Co. 421 and Co. L. 5. Next in order stands Co. L. 7 ; Co. 395 and Co. 312 happen to be the least infested. During November the pest was rather inactive and all the varieties had about the same percentage of infested shoots and had the same population. It is thus evident that the susceptibility of different varieties to sugarcane black bug can be best judged during August, when the pest is active ; during April and November varietal differences are not clearly marked.

Observations were also made to analyze the factors responsible for causing variation in black bug infestation in the five sugarcane varieties under study. As the insects were found located inside leaf-sheaths, detailed particulars of the leaf-sheaths in each variety were recorded. Area of the leaf-sheath and the nature of its connection with the cane stem, were worked out. For this purpose, 3rd*, 7th and 11th leaf-sheaths were selected and in each variety measurements of 150 leaf-sheaths of infested canes selected at random were taken during August and November. For finding out the leaf-sheath area, the bottom and top breadths and lengths of sheath were measured. The distance between the cane stem and the upper end of the sheath determined the 'detachment', the downward length up to which the leaf-sheath had separated from the cane stem was determined by inserting a probing needle. On the basis of data pertaining to leaf-sheath and infestation figures in different varieties, it was concluded that variety having broader and loosely attached (having bigger 'detachment' at the top and extending downwards for a longer distance) leaf-sheaths harboured a larger number of insects and had thus higher infestation as shown in Table II.

TABLE II

Showing direct correlation between broader and loosely attached leaf-sheaths and higher infestion of black bug in different varieties

Variety	Measurements of leaf sheaths			
	A Average area in sq. inches)	B Average top detachment (in inches)	C Average detached length (in inches)	A×B×C
Co.421	28·02	1·065	11·72	349·74
Co.L.5	20·17	1·040	10·75	255·50
Co.L.7	17·05	1·385	9·81	231·65
Co.312	17·91	1·015	10·51	191·15
Co.395	17·62	0·835	10·11	148·74

* Numbering of leaf-sheaths starts from bottom of the plant

Table III

The average population of insects on different leaf-sheaths along with average percentage of canes having black bugs on different leaf-sheaths

Time of observation	Average population of insects on different leaf-sheaths																				S.E.	Significant difference
April	Leaf-sheath number	4	3	2	1																	0·132
	Average population	*0·242	0·117	0·068	0·010																0·061	0·312
August	Leaf-sheath number	3	2	1	4	5	6	7	8	9	10										0·109	0·312
	Average population	1·376	1·325	1·026	1·023	·381	·165	·057	·019	0·011	·001											0·419
November	Leaf-sheath number	4	5	7	6	3	8	9	10	11	12	2	13	14	15	16	17	18	1			0·755
	Average population	1·331	1·305	1·248	1·237	1·186	1·82	1·04	·94	·62	·56	·33	·29	·18	·08	·047	·02	·002	·007		0·282	0·985
	Average percentage of canes having black bugs on different leaf-sheaths																					
April	Leaf-sheath number	4	3	2	1																4·815	10·493
	Percentage of canes having black bug on these leaf-sheaths	16·86	9·64	3·84	1·46																	14·711
August	Leaf-sheath number	3	2	1	4	5	6	7	8	9	10										2·107	6·041
	Percentage of canes having balck bug on these leaf-sheaths	42·24	39·68	32·78	27·86	14·82	8·44	2·78	1·30	0·58	0·14											8·103
November	Leaf-sheath number	4	5	7	8	6	3	9	10	11	12	2	13	14	15	16	17	18	19	1	2·983	8·404
	Percentage of canes having black bug on these leaf-sheaths	61·39	58·1	57·2	56·1	55·7	54·2	46·2	44·2	30·1	23·1	16·7	13·8	9·23	4·94	2·07	1·19	0·56	·066	·028		11·153

* The figures having a common line below do not exhibit any significant difference between them but are significantly different from others.

Table IV

Population of black bug on different parts during different months

Time of observation	Number of black bug inside																			
	1st*	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	Top-whorl
April	0·023	0·070	0·119	0·244																4·510
August	1·026	1·327	1·376	1·023	0·381	0·165	0·057	0·019	0·010	0·001										2·691
November	0·007	0·336	1·186	1·371	1·305	1·237	1·25	1·182	1·040	0·950	0·630	0·567	0·290	0·176	0·088	0·047	0·019	0·009	0·0001	0·000

* 1st to 19th denotes 1st to 19th leaf-sheaths

The population of the pest on an infested shoot was not uniformly distributed inside different leaf-sheaths. Moreover, the relative abundance of the insect inside different leaf-sheaths varied at different times of the season. Actual record of the number of insects found inside every leaf-sheath of 300-500 canes in each variety was maintained during April, August and November and it was observed that the trend was the same in all the varieties. The percentage of infested canes having insects inside differnt leaf-sheaths, along with the average population thereon, recorded at different times of the year, is given in Table III.

It will be observed from the Table III that during April, the population of the pest was maximum inside the 4th leaf-sheath and also a higher percentage of infested shoots had insects inside this particular leaf-sheath. During August, the population of the pest was the highest in the 3rd and the 2nd leaf-sheaths: next in order were the 1st and the 4th. The population decreased from the 4th to the 10th. The order of significance in this respect has been shown in Table III by drawing horizontal lines. The low population of the pest inside the 1st leaf-sheath was low probably due to the fact that this part of the plant was almost in the soil and was smeared with mud and water. During November, however, the population was the highest inside the 4th, 5th, 7th, 6th and 3rd leaf-sheaths. The order of significance during this period also has again been shown by drawing lines in Table III. It was also observed that leaf-sheath having the highest population of insects was the most frequently infested. Thus the 'population' and the 'percentage' have similar trends. The distribution of the pest inside different leaf-sheaths had revealed that, in most cases, the infestation was confined to the 3rd to 6th leaf-sheaths. This point is of practical importance as for recording infestation figures for comparing different varieties of sugarcane, quite accurate data can be collected by examining only the 3rd to 6th leaf-sheaths and lot of time and labour saved.

Migration of the pest

(1) *Seasonal migration*

It was observed that insects had different population densities on different parts during different times of the year. During April, all the infested cane shoots had about 4·5 insects in the top-whorl; during August only about 30 per cent of the infested cane shoots harboured about 2·7 insects in this part, while during November there were no insects in the top-whorl. The population inside different leaf-sheaths was also widely different during different periods of the year as shown in Table IV.

Furthermore, the nymphs and adults seem to have preferences for resting on different parts of a plant. Detailed observations were made on the number of nymphs and adults inside different leaf-sheaths during August, when the pest was found both in the adult and nymphal stages. There were more nymphs than the adults inside first leaf-sheath but in subsequent leaf-sheaths the number of nymphs decreased and that of the adults correspondingly increased. However, in the top-whorl, the population of nymphs was many times more than that of adults. Details are shown in Table V.

Table V

Average ratio of nymph/adult population on different parts of the cane-shoots in different varieties during August

Part of the plant	Co.L.5	Co.L.7	Co.312	Co.395	Co.421
1st leaf-sheath	6·4	6·64	1·5	5·37	1·9
2nd ,,	3·11	2·96	1·76	2·9	2·26
3rd ,,	1·46	1·16	1·26	1·74	1·37
4th ,,	·92	1·62	·83	1·9	·94
5th ,,	·43	·75	·73	2·28	·4
6th ,,	·68	·21	·17	·88	·67
7th ,,	·18	·08	·24	·36	·41
8th ,,	·02	†	†	†	·26
9th ,,	†	·019	†	†	·019
10th ,,	†	*	*	†	†
Top-whorl	38·5	28·6	42·3	55·7	9·5

* Adults and nymphs both absent
† Adults present but nymphs absent

(II) *Daily migration*

During April when the plants are young and the season warms up the insects were observed to change places during different hours of the day. In the morning they were found distributed all over the plant but as the day advanced they migrated upwards and at noon all of them congregated inside the top-whorl. In the evening the insects again migrated back to the lower portions of the plant. Results of several days' observations during April, 1944 are presented in Table VI.

TABLE VI

Distribution of black bug on a plant at different hours

Time of observation	Population of black bugs inside				
	1st leaf-sheath	2nd leaf-sheath	3rd leaf-sheath	4th leaf-sheath	Top whorl
7 A.M.	6	28	38	66	972
8 A.M.	2	11	55	81	1059
9 A.M.	5	12	21	63	1102
10 A.M.	7	17	24	102	1153
11 A.M.	3	15	20	34	1164
12 Noon	0	2	1	4	1278
6-30—7-30 P.M.	25	120	80	35	980

SUMMARY

Sugarcane black bug (*Macropes excavatus* Dist.) is one of the destructive and widely distributed pests of sugarcane in the Punjab. Observations on the behaviour of this pest in five varieties of sugarcane at different stages of crop growth were made during 1943 and 1944. Varietal differences with respect to the incidence of this pest are significant only during August when the pest was most active. The varieties having broader and loosely attached leaf-sheaths were more heavily infested. The pest was not uniformly distributed over the infested shoot: heavy infestation was mostly confined to the third to sixth leaf-sheaths. This point is of practical importance as during active period of the pest quite accurate data on the infestation in different varieties and in plots receiving different treatments, can be collected by examining only these particular leaf-sheaths and lot of time and labour saved. The intensity of population on different parts of a plant fluctuated at different times of the season; when the plants were young, the insects were observed to change places during different hours of the day.

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DAMAGE TO THE WHEAT CROP BY RUST IN RELATION TO VARIETY AND TIME OF SOWING

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An outbreak of black stem rust, *Puccinia graminis* tritici, in an epidemic form, marked the wheat growing season of the year 1943-44. With a view to assess the damage caused to the standing crop, a survey was undertaken in the affected parts of this province and it was observed that, among other things, the time of sowing and the kind of variety grown, principally determined the extent of loss. This visual observation was verified by actual estimation in an experiment which was laid out at Government Farm, Dindori (Mandla District), primarily to ascertain the effect of frost and was to be rejected as there was no frost in that season.

In the experiment referred to above, seven wheat strains, *viz.*, I.P.52, I.P.101, A013, A049, A068, A090, A115 and a local variety (which from the plant characters was found to be A090, the strain grown on a large scale in the locality), were sown on three different dates, *viz.*, 23-10-43, 8-11-43 and 19-11-43, in six replications. The layout was of the split-plot design, with sowing date as the major treatment, varieties being superimposed. The 144 plots were divided into two equal halves from each of which, 8 lines, 2 ft. long were harvested and bulked. Although, both the weight of the produce so obtained and that of the 1,000 grains therefrom were recorded, the actual loss by rust was calculated from the latter. It is a common knowledge that yield is influenced by a variety of factors amongst which plant population surviving at harvest is the most significant and it is this factor which varies greatly in different sowings. On the other hand kernel weight is not appreciably influenced, within certain limits, by sowing time as will be evident from the figures given in Table I.

Table I

1,000 kernel weight of I.P.52, sown at intervals, at Government Farm, Saugor, 1943-44

Sown on	Weight
6-10-43	33·2 gm.
5-11-43	29·0 „
5-11-43	30·3 „

The figures of 1,000 grain weights from the 288 sub-plots were statistically analyzed and the results obtained, are summarized in Table II.

Table II

Mean 1,000 grain weight in grammes of different varieties sown at intervals

Sowing time	Varieties								Mean	S.E.
	I. P. 52	I.P. 101	A 013	A 049	A 068	A 090	A 115	Local		
Early	25·13	33·61	35·72	36·75	36·67	31·12	30·22	31·96	34·64	0·3649
Normal	20·37	20·40	16·21	14·63	17·40	16·90	18·12	17·80	17·72	
Late	[illegible]·92	10·97	9·56	9·56	8·83	10·27	10·71	10·14	10·22	
Mean	22·41	21·66	20·49	20·31	20·96	19·42	21·68	19·96		
S.E				0·3140						

The association of highest grain weight with early sowing in all varieties is indicative of the least damage by rust, which increased significantly with delayed sowing.

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Since grain weight is not constant in all varieties, their comparison based simply on their 1,000 grain weights will not be valid. However, the loss in the weight by delayed sowing, within the self-same variety, would indicate the extent to which it has suffered. This has been calculated and shown in Table III.

TABLE III

Loss in 1,000 grains weight (in grammes) of varieties due to delayed sowing

Variety	Loss in weight between early and normal sowings	Loss in weight between early and late sowings
I.P.52	4·76	16·2
A115	12·10	19·51
I.P.101	13·21	22·64
Local (A090)	14·16	21·82
A090	14·22	20·85
A068	19·27	27·84
A013	19·51	26·16
A049	22·12	27·19

It will be seen that the varieties have sustained a loss to a varying degree. I.P.52 showed the least damage, whereas A068, A013 and A049, were most affected.

SUMMARY

An attempt has been made to indicate the damage caused to the wheat crop by rust in relation to the variety grown and the time of sowing.

It was observed that, among other things, the time of sowing and the kind of variety grown principally determined the extent of loss.

THE EFFECT OF FROST ON DIFFERENT WHEAT VARIETIES SOWN AT INTERVALS

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(Received for publication on 24 June 1946)

THE wheat crop in the northern part of this province is subjected to occasional damage by frost. In the year 1928-29, an excellent crop was outright destroyed overnight and although such a widespread and calamitous damage has not occurred since then, sporadic attacks have been reported off and on.

In the absence of facilities for artificial testing, experiments were laid out on different farms to ascertain varietal reaction and the effect of time of sowing on the extent of damage under natural conditions of frost occurrence. In these experiments, seven wheat strains, A013, A049, A068, A090, A115, I.P.52, I.P.101 and a local variety were sown on three different dates, *i.e.*, 19-10-42, 29-10-42 and 17-11-42, in six replications. The layout was of the split-plot pattern.

At the Government Farm, Saugor, one of the stations where the experiment was laid out, there was frost on the 7th, 8th and 9th February, 1943, of mild intensity. As the damage was sporadic, the following sampling method was adopted to estimate the same. Four unit areas, each 4 ft.×4 ft., were marked out in the affected portions of each plot and the number of affected and normal ears were counted from each of them. The ears were threshed separately and the weight of produce therefrom was recorded. The effect of frost on yield of grain was determined by calculating the difference in the grain weight of the frosted and an equal number of unaffected ear-heads.

The data thus collected was analyzed statistically and the results obtained are given in Table I and II.

TABLE I

Mean loss in yield in different sowings lb. per acre

Sowing time	Mean loss	Standard error
Early sowing (19-10-42)	23·18	3·32
Normal sowing (29-10-42)	20·87	
Late sowing (17-11-42)	13·54	

TABLE II

Mean loss in yield of grain of different varieties in lb. per acre

Variety	Mean loss	Standard error
I.P.101	10·77	2·65
I.P.52	11·87	
A115	16·44	
A090	17·65	
A013	20·13	
A049	21·64	
A068	21·74	
Local	32·52	

It is evident that the effect of time of sowing the crop on the extent of frost damage, is not significant although the figures indicate that the loss was less with delayed sowing.

Varietal reaction is, however, clearly perceptible in the case of the local variety, which suffered most and I.P.101 and I.P.52, which sustained the least damage. Strains A115 and A090, too, did not suffer to the extent to which A013, A049, A068 and the local did, although the differences in the loss of yield between them are not in all cases statistically significant.

Summary

Experiments were carried out to ascertain varietal reaction and the effect of time of sowing on the extent of damage under natural conditions of frost occurrence.

The effect of time of sowing the crop on the extent of frost damage was not significant. Varietal reaction on the other hand was clearly perceptible as between certain varieties experimented with.

RESEARCH NOTE

VERNALIZATION, AN AID IN CROP BREEDING

By R. B. Ekbote, Wheat Research Station, Powarkhera, C. P.

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FROM among the wheat varieties obtained from countries outside India, a few were found to be highly resistant to black rust. The use of these strains as parents for crossing with the local varieties, however, presented difficulty on account of their late earing character. To overcome this handicap, an attempt was made to induce early flowering in them, by means of vernalization. For want of a refrigerator or an electorlux, the treatment was carried out in a wide-mouth thermo-flask. Petri-dishes containing the sprouted seeds were placed in a tiffin-carrier which was inserted in the flask. Sufficient ice was added from the sides and on the top of the tiffin-carrier and the supply of ice was replenished off and on. The temperature inside the flask remained 8° to 10° C. The treatment was carried out for 10 days after which the treated seeds were taken out and sown in earthen pots. The untreated seeds, *i.e.*, the controls, were sown in the field. As a result of the treatment, earing was accelerated by 23, 19 and 3 days in E.144, Ex.30 and *Khapli* (*T. dicoccum*), respectively.

In the following year, *i.e.*, 1943-44, salt was added with ice and the mixture was changed more frequently with the result that the temperature inside the flask could be brought down to about 6° C. The period of treatment could, therefore, be prolonged to 25 days. This time, both the treated and untreated seeds were sown in the pots. The former showed an acceleration over the control by 47 days in the case of Ex.30, 35 in Ex.3, 29 in E.144 and 28 in *Khapli*.

The results were very encouraging and enabled the crossing work being taken up from as early as the last week of December.

Judged by the reaction shown by the foreign wheat varieties tried, vernalization is considered to be a distinct aid in crop breeding work.

REVIEW

THE NEW GENETICS IN THE SOVIET UNION

By P. S. HUDSON and R. H. RICHENS (Published by Imperial Bureau of Plant Breeding and Genetics, Cambridge, 1946) Price 6s.

THE genetics controversy associated with the name of the Russian agronomist, T. D. Lysenko, has now become well-known and has excited a great deal of interest among the scientific workers all the world over. The history of genetical researches in Russia during the last ten years, or a little over, appears strange to outsiders and much confusion exists in the minds of scientists as to the present position of these researches in that country. Scientific theories are known to transcend geographical boundaries and until the end of the third decade there was, as was to be naturally expected, little difference in the genetical theories held in Russia and those in other countries. But some time in 1935, a new school of genetics arose in Russia under the leadership of Lysenko which put forward certain theories very different from those of other geneticists. This gave rise to a great deal of controversy for sometime: gradually the new school of Lysenko and his colleague Prezent became dominant and came to occupy a very prominent place in the U.S.S.R. as a result of the large amount of official support it received.

Attempts have been made in the past by different authors to analyze the theories of Lysenko's School, but the views expressed by them have often been emotional and, as such, a fair criticism of the theories has not been possible. The name of Lysenko has given rise to some sort of prejudice and the new theories have sometimes been condemned by reviewers as absolutely invalid and unscientific and straightaway rejected, although adequate relevant data were not available to people outside Russia. What was needed was an impartial statement without any prejudice whatsoever which would enable the reader to form a correct idea of the actual position of genetical researches in the U.S.S.R. The authors of the present bulletin, Dr Hudson and Dr Richens, have put before the public a very carefully prepared critical statement and have dealt with the relevant facts impartially. In fact this is the first real attempt to give a detailed objective account of the controversy, based exclusively on Russian publications.

It is pointed out that the ideas of Lysenko's School are based on the philosophy of dialectical materialism and they have been very greatly influenced by the writings of Darwin, Micurin and Burbank.

The bulletin is divided into six chapters, the first one being a short introduction to the subject. The historical and psychological background, against which the new theories have developed, has been discussed in the next two chapters. The authors have done well in prefacing the detailed account of the present position of genetical researches in the U.S.S.R. by a clear exposition of the background, since a knowledge of the latter is very necessary for understanding the modern Russian outlook.

The fourth chapter deals with a summary of a very large volume of experimental results claimed by Lysenko's School as evidence in support of its genetical theories. They have been critically discussed under twelve headings, *viz.*, the genetics of earliness, the prediction of dominance, degeneration of pure lines, rejuvenation, induced mutation, segregation, millardetism, F_1 heterogeneity, reciprocal hybridization and internal genetic variation, mixed inheritance, graft hybridization. With regard to the last one, the authors of the bulletin hold the view that further experiments are necessary for coming to a definite conclusion. They state that in most of the other cases the point is not proved by the evidence put forward, or even if proved, as in a few cases, it is nothing new. Lysenko and his followers have stated that the above results hold good under appropriate environmental conditions, but curiously enough these conditions are not specified by them. There have been objections to acceptance of many of these experimental results on account of defective experimental procedures described. The antipahty of Lysenko's school to statistical analysis, even though most of the evidence is quantitative makes its validity still more doubtful.

The theories put forward by Lysenko and Prezent to explain all genetical facts and their own results are dealt with in the next chapter. The most important of their hypotheses is the theory of

'nutrients'. The authors of the bulletin present a critical analysis of the theories to prove their validity or otherwise. They state that a serious general criticism which applies to all aspects of Lysenko's nutrient theory is that it has never been investigated physiologically. According to them 'Nutrients are invoked to explain every kind of genetical phenomenon, but very seldom is any attempt made to specify what the relevant nutrients are, or what is the mode of their action.'

Lysenko and his followers have advanced arguments against Mendelism and indeed have attempted to overthrow modern genetics. Their criticism has been dealt with in the sixth chapter of the bulletin. Much of the criticism of Mendelism by this School owes its origin to the fact that the former does not conform to dialectical materialism and the recognized authorities, *viz.* Darwin, Micurin, Timirjazev and Burbank. Hudson and Richens discuss these arguments critically and state that many of these are worthless, since the new School attacks genetics of thirty years ago. It appears that Lysenko and Prezent are not familiar with modern genetical theories and, therefore, much of the criticism loses its value.

The authors have been quite successful in their attempt to present a detailed and critical account of the very controversial subject. Credit is all the more due to them for remaining impartial while discussing the different theories of the new School and analyzing the merits and defects of the arguments of Lysenko and his followers. The restrained language used and the impartiality shown by the authors will, it is hoped, be of the utmost help in removing the misunderstanding that now exists between the school of Lysenko and that of international genetics, and encourage cooperative work by them which is very necessary for arriving at definite conclusions regarding some of Lysenko's results.

The authors have taken great pains in preparing this well-written treatize which will prove very valuable to all scientific workers.

There is a bibliography of about 300 references and all important statements of authors quoted are given in the original language as well as in English.

MGIPC—M—III-1-16—23-7-48—600.

ORIGINAL ARTICLES

VARIATIONS IN THE PROPERTIES OF THE COTTON FIBRE IN RELATION TO ITS POSITION ON THE SURFACE OF THE SEED II

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(With nine text figures)

THE problem of the variation in fibre properties on the surface of the seed of a number of standard Indian cottons has been dealt with in an earlier publication [Koshal and Ahmad, 1932] in which the results of an investigation relating to fibre-length, fibre-weight per inch and fibre-strength were described in detail. The present paper contains an account of a similar investigation with respect to three other remaining properties, namely, fibre-rigidity, ribbon-width and convolutions per inch, using the same standard Indian cottons.

Material

The material used in this investigation was the same as that on which tests were made by Koshal and Ahmad [1932], the slivers having been prepared conjointly by us.

Only in the case of Nandyal 14 fibres from all the four regions of the seed (base, apex, right flank, left flank) and the combed fibres were tested, while in the case of the other cottons the fibres from the basal and the apical regions were examined.

Methods

The methods adopted in the determination of the above properties are the same as have been described by Ahmad [1933]. It should, however, be made clear that for each cotton the same set of fibres were used in successive determinations of the three properties. (The method of determining fibre-rigidity is especially dealt with in the Appendix.) The statistical methods applied were similar to those employed by Koshal and Ahmad [1932].

Discussion of results

(Fibre rigidity)

(a) *Base and Apex.*

The frequency distributions for fibre-rigidity for the fibres taken from the basal and the apical regions of the seeds of eight Indian cottons are shown in Table I.

Table I

Frequency distribution—fibre rigidity, base and apex

Dynes Cm.^{2} 10^{-3}	Nandyal 14		P. A. 4F.		C. A. 9 (1928-29)		C. A. 9 (1929-30)		Gadag 1 (1928-29)		Gadag 1 (1927-28)		Verum 262 (Nagpur)		Surat 1027 A. L. F.	
Group	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
0 . .	18	6	36	5	6	1	15	1	18	2	19	0	15	0	40	3
1 . .	28	11	42	7	24	5	28	10	61	6	53	13	30	5	34	11
2 . .	25	19	32	14	34	22	34	23	30	24	41	6	20	5	18	18
3 . .	21	29	22	19	32	28	25	41	16	25	17	21	19	8	14	26

A

TABLE I

Frequency distribution=fibre rigidity, base and apex

Dynes Cm.² 10² Group	Nadyal 14		P. A. 4F,		C. A. 9 (1928-29)		C. A. 9 (1929-30)		Gadag 1 (1928-29)		Gadag 1 (1927-28)		Verum 262 (Nagpur)		Surat 1027 A. L. F.	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
4 . .	19	26	11	27	19	33	22	30	10	26	14	19	18	10	8	15
5 . .	10	20	6	19	13	19	18	17	10	14	6	17	8	19	9	13
6 . .	16	12	2	22	12	20	1	13	0	20	1	17	10	18	5	8
7 . .	5	12	2	12	5	4	4	9	1	15	1	18	8	16	6	7
8 . .	2	7	0	7	2	7	1	4	2	10	1	15	5	14	2	11
9 . .	1	4	1	9	2	3	1	1	0	4		10	5	10	3	8
10 . .	1	5	1	4	1	3	0	1	1	5		6	2	8	4	6
11 . .	1	2		0		1	0		0	2		2	1	5	3	1
12 . .	0	1		2		0	1		1	0		2	5	7	1	4
13 . .	0			3		3				2		2	3	3	2	6
14 . .	1											1	0	3	0	1
15 . .													0	3	0	2
16 . .													2	1	0	2
17 . .													0	2	0	0
18 . .													0	5	0	0
19 . .													0	0	0	1
20 . .													0	2	1	1
21 . .													1	1		0
22 . .														3		2
23 . .														1		1
24 . .														0		1
25 . .														1		0
26 . .														3		0
27 . .																0
28 . .																1
29 . .																1
30 . .																1
Total No. of tests	148	154	155	150	150	149	150	150	150	153	153	149	152	153	150	151

B=Base; A=Apex

The mean values and all the statistical constants calculated from these distributions are given in Table II.

TABLE II

Frequency constants for frequency distributions of fibre rigidity—base and apex

No.	Cotton	Region	Mean M	$\frac{A-B}{B} \times 100$	..	Cv	Q_1	Q_2	e_1	e_2	$\frac{Q_3-Q_1}{2}$ =Q	E (S. O.)	$\frac{e_1-e_2}{M}$ C. A.	Ed	$\frac{M\text{-Mode}}{..}$ =Skewness
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Nandyal 14	Base	3·11	42·2	2·44	78·3	1·19	4·55	1·92	1·44	1·68	1·64	0·154	56·8	0·513
		Apex	4·42		2·55	57·6	2·63	5·92	1·79	1·50	1·64	1·72	0·064		0·528
2	P. A. 4F	Base	1·97	156·8	1·75	88·4	0·61	2·83	1·36	0·86	1·11	1·18	0·252	110·4	0·748
		Apex	5·06		2·74	54·0	3·15	6·52	1·91	1·46	1·69	1·84	0·088		0·390
3	C. A. 9 (1928-29)	Base	3·26	39·6	2·00	61·4	1·77	4·42	1·49	1·16	1·32	1·35	0·100	53·8	0·546
		Apex	4·55		2·40	52·7	2·88	5·74	1·67	1·18	1·43	1·62	0·108		0·555
4	C. A. 9 (1929-30)	Base	2·82	38·0	1·94	68·9	1·35	4·03	1·46	1·21	1·34	1·31	0·090	60·0	0·504
		Apex	3·89		1·55	39·7	2·64	4·99	1·26	1·10	1·18	1·04	0·040		0·647
5	Gadag 1 (1928-29)	Base	2·00	138·5	1·87	93·6	0·97	2·77	1·18	0·77	0·97	1·26	0·205	104·6	0·772
		Apex	4·77		2·32	48·9	2·80	6·44	1·97	1·67	1·81	1·57	0·064		0·604
6	Gadag 1 (1927-28)	Base	1·99	183·4	1·44	72·4	0·91	2·65	1·08	0·66	0·87	0·97	0·208	122·2	0·687
		Apex	5·64		2·87	50·8	3·42	7·60	2·22	1·96	2·09	1·93	0·046		0·187
7	Verum 262	Base	4·17	110·3	3·78	90·6	1·32	5·95	2·85	1·78	2·32	2·55	0·257	99·0	0·249
		Apex	8·77		5·57	63·5	5·09	10·90	3·68	2·13	2·91	3·76	0·177		0·808
8	Surat 1027 A. L. F.	Base	3·00	122·0	3·43	114·4	0·49	4·36	2·52	1·36	1·94	2·32	0·385	83·0	*
		Apex	6·66		6·14	92·3	2·77	8·71	3·89	2·05	2·97	4·14	0·276		0·935

.. =Standard Deviation
Cv=Coefficient of Variation
B=Base
A=Apex

Q_1=Lower Quartile
Q_3=Upper Quartile
Q=Semi Inter-Quartile Range
E=Probable Error of (S. O.) single observation
Ed=Total percentage divergence between Base and Apex
* =Skewness not calculable

e_1=Distance of mean from Q_1
e_2=Distance of mean from Q_3
$\frac{e_1-e_2}{M}$=Coefficient of Asymmetry=C. A.

The mean values and their differences which are given in columns 4 and 5 of Table II, may be considered first. It is found that in the case of all cottons the apical fibres possess higher rigidity than the basal fibres; the differences in the mean values, calculated in terms of the basal fibres are, however, not the same for the different cottons, but vary from 38·0 per cent for C. A. 9 (1929-30) to 183·4 per cent for Gadag 1 (1927-28), showing a great dissimilarity of behaviour in this respect by the different cottons. These differences are all in the same direction, and are, on the whole, large; but, before we may draw any conclusions from them, it is necessary to apply some criteria of significance. The need for applying some such criteria becomes evident when we consider the values of coefficient of variation for this property given in column 7 of Table II. It will be seen that this statistic varies from 39·7 to 114·4, showing the extreme dispersion in this property from fibre to fibre in the same sample. Now, in a normal distribution the standard error test would be adequate, but an inspection of Table I would show that the values obtained for this property are very asymmetrically distributed, which is also evident from the disparity in the values of e_1, e_2, Q and E (S. O.). Hence in the present case the standard error test cannot be applied and it is proposed to apply the following criteria.

In the first place it will be noticed that, for all cottons, except Nandyal 14 and C. A. 9 (1929-30), the mean value for the apical fibres is greater than the upper quartile for the basal fibres. Even in the case of these two exceptions the upper quartile for the basal fibres is very nearly equal to the mean for the apical fibres, showing clearly that there is a predominance of fibres of greater rigidity in the apical region of the seed and of fibres of lower rigidity in the basal region.

In order to judge the results more rigorously, we can apply a test known as percentage divergence test. For this purpose the frequencies are calculated on percentage basis for the different groups; the difference between the basal and the apical values for each individual group is shown in Table III.

TABLE III

Percentage frequency distribution of fibre rigidity, and divergence percentage

Dynes cm.$_2$ 10-$_2$ Group	Nandyal 14			P. A. 4F.			C. A. 9 (1928-29)			C. A. 9 (1929-30)		
	B	A	A-B	B	A	A-B	B	A	A-B	B	A	A-B
0	12·2	3·9	—8·3	23·2	3·3	—19·9	4·0	0·7	—3·3	10·0	0·7	—9·3
1	18·9	7·1	—11·8	27·1	4·7	—22·4	16·0	3·4	—12·6	18·6	6·7	—11·9
2	16·9	12·3	—4·6	20·7	9·3	—11·4	22·7	14·8	—7·9	22·6	15·3	—7·3
3	14·2	18·9	4·7	14·2	12·7	—1·5	21·3	18·8	—2·5	16·7	27·3	10·6
4	12·8	16·9	4·1	7·1	18·0	10·9	12·7	22·1	9·4	14·6	20·0	5·4
5	6·8	13·0	6·2	3·9	12·7	8·8	8·7	12·7	4·0	12·0	11·2	—0·8
6	10·8	7·8	—3·0	1·3	14·7	13·4	8·0	13·4	5·4	0·7	8·7	8·0
7	3·3	7·8	4·5	1·3	8·0	6·7	3·3	2·7	—0·6	2·7	6·0	3·3
8	1·3	4·5	3·2	0·0	4·7	4·7	1·3	4·7	3·4	0·7	2·7	2·0
9	0·7	2·6	1·9	0·6	6·0	5·4	1·3	2·0	0·7	0·7	0·7	0·0
10	0·7	3·3	2·6	0·6	2·6	2·0	0·7	2·0	1·3	0·0	0·7	0·7
11	0·7	1·3	0·6	0·0	0·0	0·0	0·0	0·7	0·7	0·0	0·0	0·0
12	0·0	0·6	0·6	0·0	1·3	1·3	0·0	0·0	0·0	0·7	0·0	—0·7
13	0·0	0·0	0·0	0·0	2·0	2·0	0·0	2·0	2·0			
14	0·7	0·0	—0·7									
15												
16												
17												

TABLE III

Percentage frequency distribution of fibre rigidity and divergence percentage

Dynes cm² 01-2	Nandyal 14			P. A. 4F.			C. A. 9 (1928-29)			C. A. 9 (1929-30)		
Group	B	A	A-B	B	A	A-B	B	A	A-B	B	A	A-B
18												
19												
20												
21												
above 22 . . .												
Divergence : . .			56·8			110·4			53·8			60·0

B=Base; A=Apex

Gadag 1 (1928-29)			Gadag 1 (1927-28)			Verum 262			1027 A. L. F.		
B	A	A-B	B	A	A-B	B	A	A-B	B	A	A-B
12·0	1·3	—10·7	12·4	0	—12·4	9·9	0	—9·9	26·6	2·0	—24·6
40·6	3·9	—36·7	34·6	8·7	—25·9	19·7	3·3	—16·4	22·7	7·2	—15·5
20·0	15·8	—4·2	26·8	4·0	—22·8	13·2	3·3	—9·9	12·0	11·9	—0·1
10·6	16·3	5·7	11·0	14·2	3·2	12·5	5·2	—7·3	9·4	17·2	7·8
6·7	17·0	10·3	9·2	12·8	3·6	11·8	6·5	—5·3	5·3	10·0	4·7
6·7	9·1	2·4	3·9	11·4	7·5	5·2	12·4	7·2	6·0	8·6	2·6
0·0	13·1	13·1	0·7	11·4	10·7	6·6	11·9	5·3	3·3	5·3	2·0
0·7	9·8	9·1	0·7	12·1	11·4	5·2	10·5	5·3	4·0	4·6	0·6
1·3	6·5	5·2	0·7	10·1	9·4	3·3	9·1	5·8	1·3	7·2	5·9
0·0	2·6	2·6	0·0	6·7	6·7	3·3	6·5	3·2	2·0	5·3	3·3
0·7	2·0	1·3	0·0	4·0	4·0	1·3	5·2	3·9	2·7	4·0	1·3
0·0	1·3	1·3	0·0	1·3	1·3	0·7	3·3	2·6	2·0	0·7	—1·3
0·7	0·0	—0·7	0·0	1·3	1·3	3·3	4·6	1·3	0·7	2·7	2·0
0·0	1·3	1·3	0·0	1·3	1·3	2·0	1·9	—0·1	1·3	4·0	2·7
			0·0	0·7	0·7	0·0	1·9	1·9	0·0	0·7	0·7
						0·0	1·9	1·9	0·0	1·3	1·3
						1·3	0·7	—0·6	0·0	1·3	1·3
						0·0	1·3	1·3	0·0	0·0	0·0
						0·0	3·3	3·3	0·0	0·0	0·0
						0·0	0·0	0·0	0·0	0·7	0·7
						0·0	1·3	1·3	0·7	0·7	0·0
						0·7	0·7	0·0	0·0	0·0	0·0
						0·0	5·2	5·2	0·0	4·6	4·6
		104·6			122·2			99·0			83·0

The individual divergences added up (irrespective of sign) give the total percentage divergence between the values for the two regions of the seed. If in a given case, the difference for the two regions of the seed is not significant, then not only would the total divergence be small, but the individual values of divergence would be nearly alternately positive and negative. It will be seen from Table III that this is not the case for any one of the cottons. In almost every case the divergences

are negative in the first three or four groups and positive in the remaining groups and the total divergence is high, ranging from 53·8 to 122·2. Considering the case of Nandyal 14, for which the quartile test was inconclusive, the divergence is negative in the first three groups and, except for the 6th and the 14th, positive in all the other groups. The total divergence is also high, being 56·8. Similarly, in the case of C. A. 9 (1928-29), the total divergence is 53·8, the first four groups are negative and except for the seventh group all others are positive. For the same cotton of the following season the total divergence is 60·0, the first three groups are negative and, excepting the fifth, and the twelfth groups, all the others are positive. This analysis shows that even for these cottons the differences in mean values are significant, although they are small as compared with the others, which therefore must be highly significant.

We are thus led to conclude that fibres on the apical region of the seed possess higher fibre-rigidity than those on the basal region, the difference between the mean values for the two regions, varying from cotton to cotton.

The frequency distribution curves for the basal and the apical fibres for all the eight cottons are given in Fig. 1.

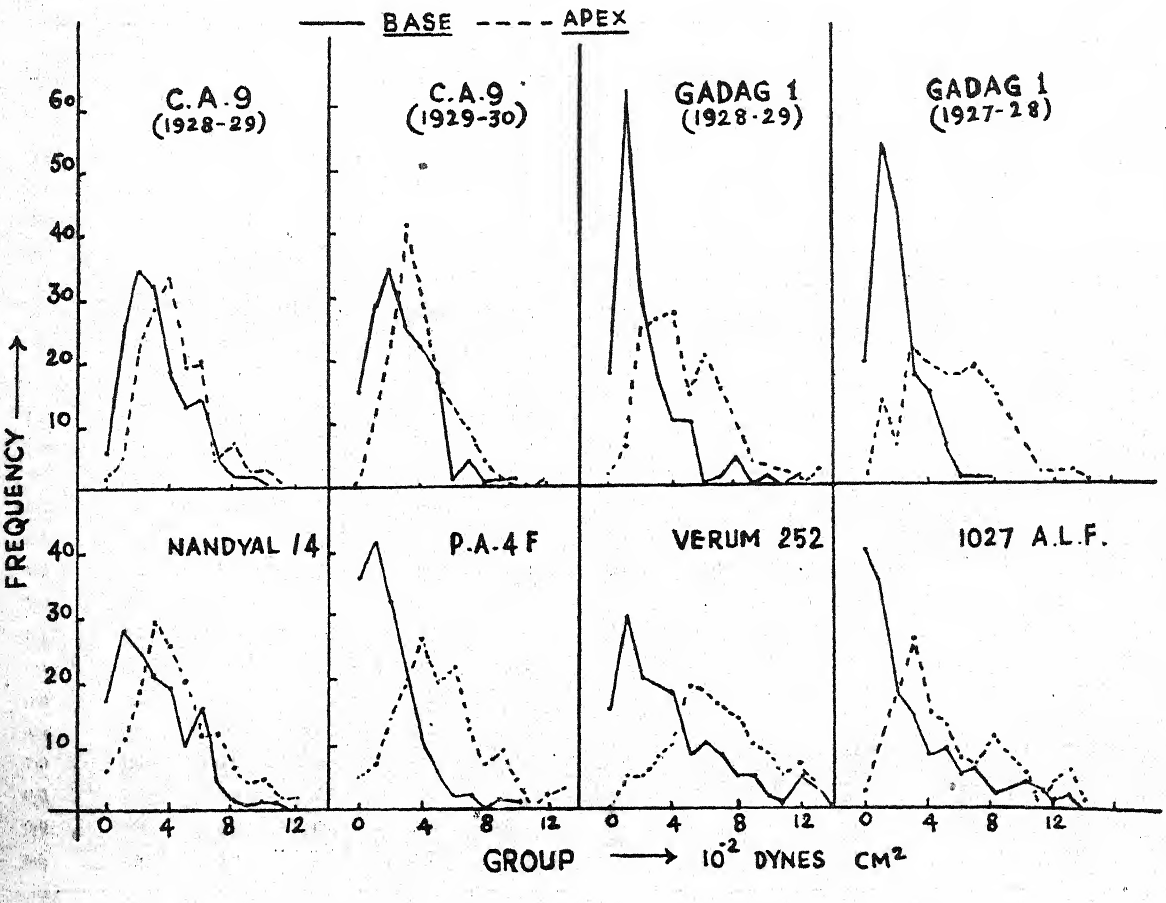

FIG. 1.

It is seen from these that all the curves deviate from the normal. This observation is supported by the high coefficient of asymmetry found for both the apical and the basal fibres, which are given in column 14 of Table II.

Comparing the curves for the apical and the basal fibres it is noticed that the distribution in the former is skew, while it shows a distinct tendency to J-shape in the latter. The comparatively lower values of the coefficient of asymmetry for the apical distributions (except for C. A. 9—1928-29, where it is nearly equal), as well as the lower values of the coefficient of variation for the apical fibres, afford statistical evidence for the greater departure from normality for the basal distributions.

A visual inspection of these curves shows that the cottons may be classified as follows under three heads in respect of the type of frequency distribution of rigidity values for the basal fibres.

Surat 1027 A. L. F.	Pronounced J-shape.
Nandyal 14, P. A. 4F, Gadag 1 and Verum 262	J-shape.
C. A. 9	Least J-shape.

It is interesting to observe that a similar classification would result if the coefficient of variation were taken into consideration, 1027 A. L. F. having the maximum value and C. A. 9 (1928-29) the minimum value.

The cottons may also be classified in respect of the skewness of the curves for the apical fibres.

The skewness(s) is to be expressed according to Pearson's formula, $s=\dfrac{\text{mean-mode}}{\text{standard deviation}}$. The result is as follows :

Verum 262 & 1027 A. L. F. :	Largely skew (skewness 70·>50).
Nandyal 14, P. A. 4F, C. A. 9, Gadag 1 (1928-29) :	Skew (skewness between 0·250 and 0·750)
Gadag 1 (1927-28) :	Less skew (skewness <0·250)

Two different types of distribution are thus obtained for the same cotton, depending upon the region of the seed surface, the basal region giving a J-distribution and the apical region a skew distribution. This holds good more or less for all the eight cottons tested in this investigation.

We will now compare the mean values and the types of distribution for the different regions of the seed surface, with those obtained for the bulk sample and consider the effect of the former upon the latter. The values for the bulk samples are taken from *Technological Reports on Standard Indian Cottons* [Ahmad, 1931] :

TABLE IV

Comparative fibre-rigidity values ($dynes\ cm^2\ 10^{-2}$.)

Cotton	Base	Apex	Bulk
Nandyal 14	3·11	4·42	3·03
P. A. 4F	1·97	5·06	3·85
C. A. 9 (1928-29)	3·26	4·55	4·28
C. A. 9 (1929-30)	2·82	3·89	5·31
Gadag 1 (1928-29)	2·00	4·77	2·47
Gadag 1 (1927-28)	1·99	5·64	2·72
Verum 262	4·17	8·77	3·46
1027 A. L. F.	3·00	6·66	2·25

It is found there from that in the case of five cottons out of eight the mean value for the bulk lies nearer to that for the basal than for the apical fibres. Among the remaining three cases it lies midway between the two for P. A. 4F, and nearer to the apical value for C. A. 9 (1928-29), while it is higher than the values either for the basal or the apical fibres for the same cotton of the following season. Thus for a majority of the cottons the bulk mean value lies nearer to that for the basal than for the apical fibres.

In so far as the distribution of these values is concerned, it has been shown by Koshal and Turner [1930] that when a sufficiently large number of fibres of 1027 A.L.F. were tested, the bulk sample yielded a characteristically J-shaped curve of distribution for fibre rigidity. For this cotton at least, therefore, the bulk sample is similar in this respect to the basal fibres. If this were true of other cottons as well, the effect of the apical fibres on a bulk sample, either in increasing the mean value by virtue of their higher rigidity or in modifying the distribution by virtue of their skewness, is masked to a large extent by the numerical preponderance of the less rigid fibres and the strong J-tendency in their distribution. A J-shaped distribution indicates the existence of a large number of fibres of low rigidity and a comparatively small number of high rigidity; the former possibly being included among the combed hairs, which will be discussed later, and the latter among the apical fibres.

Seasonal fluctuations. Only two cottons, Gadag 1 and C. A. 9 were tested for two different seasons. From the results obtained it is interesting to note that while the regional difference in the mean values between the basal and the apical fibres varies considerably from cotton to cotton as noted earlier, for any one cotton, from season to season, the variation is much narrower. For Gadag 1 the difference is 138·5 per cent in one season and 183·4 per cent in the other, and for C. A. 9 it is 38·0 per cent in one season and 39·6 per cent in the other. It is thus found that while the ratio between the values for the basal and the apical fibres varies considerably from cotton to cotton grown in the same season, for any one cotton grown in different season, the ratio is somewhat constant. This shows that the influence of environmental factors on the relative variation in the rigidity of the fibres from different parts of the seed is fairly constant. Further, the types of frequency distributions are also nearly the same both for the apical and the basal fibres in the different seasons.

Rigidity modulus of the material of the fibres. During the measurement of ribbon-width and convolutions, the fibres of Verum 262 and 1027 A. L. F. were classified, according to their appearance under the microscope into two classes (*a*) thin ribbon-like and (*b*) stout rod-like. Rigidity tests on fibres falling in the second class, which appeared cylindrical and had few convolutions, showed that they generally possessed high values of rigidity. From these observations the rigidity modulus of the material constituting the basal and the apical fibres was calculated according to the method suggested by Peirce [1923]. The coefficient of rigidity as given by Peirce can be calculated from: $\rho^{n}=ns^{2}$ (=fibre rigidity= $\frac{8\pi^3 Il}{T^2}$ vide Appendix where ρ=couple per unit twist per unit length, s=area of cross section and E=a quantity depending on the shape of the cross section. For nearly cylindrical fibres falling in the second class E=1 and $s^2=\frac{\pi^2 S^4}{16}$ where δ is the diameter of the fibre. We thus finally have $n=\frac{16\rho}{\pi^2 S^4}$.

This formula is applicable only to those fibres which have a nearly circular cross section, a rod-like appearance and comparatively few convolutions, and only such fibres were selected for the purpose of this calculation. The final results obtained for Verum 262 and 1027 A. L. F. are given below in Table V:

TABLE V

Rigidity modulus of the material of the fibre, (base and apex)

Cotton	Region of the seed	$P=\frac{8\pi^3 Il}{T^2}$ x10^{-2} dynes cm^2	δ x10^{-2}cm	$n=\frac{16\rho}{\pi^2\delta^4}$ 10″ dynes cm^2
Verum 262 (Nagpur)	Base	10·4	0·1452	0·3791
	Apex	10·6	0·1487	0·3515
Surat 1027 A. L. F	Base	9·1	0·1832	0·1308
	Apex	10·8	0·1966	0·1171

It is seen that the rigidity modulus for the material is very nearly equal for the basal and the apical fibres of the same cotton although it varies considerably from one cotton to another. The finer variety, 1027 A. L. F., has a lower value than the coarser variety, Verum 262, its value being nearly one-third of that for the former. Peirce [1923] found that the average value of the rigidity modulus for two cottons (Sea Island and an Indian cotton) was $0{\cdot}23 \times 10''$ dynes/cm². This is nearly double of that found for Surat 1027 A. L. F. in the present tests but less than that obtained for Verum 262. These results show that the nature of the material deposited in fibres growing on different regions of a seed is the same though it may differ somewhat from cotton to cotton. Thus, if a high fibre-weight is observed for the apical fibres, it is due to the presence of a larger quantity of the material itself rather than to the deposition of a material of a higher density.

(*b*) *Fibres from all regions of the seed.*

The tests on fibres taken from all regions of the seed were confined only to Nandyal 14. The mean values of rigidity obtained for the base, apex, right flank, left flank of the seed and the combed hairs together with the absolute and percentage differences (calculated on the basis of the lower values) are given in Table VI.

TABLE VI

Fibre rigidity, 10^{-2} dynes cm² mean value differences: fibres from all regions of the seed, Nandyal 14.

Region 1	Mean 2	Difference between 3	Mean value differences 4	Percentage 5	Significant or non-significant 6
Base (B)	3·11	B—L	—0·01	0·3	Not significant
Apex (A)	4·42	B—Flanks	—0·20	6·4	Do.
Right Flank (R)	3·31	B—C	1·20	62·8	Significant
Left Flank (L)	3·32	A—Flanks	1·11	33·5	Do.
Combed hairs (C)	1·91	A—C	2·51	131·4	Do.

Several interesting points emerge from a study of Table VI. It is seen in the first place that fibre-rigidity varies considerably over the surface of the seed, the highest value for the apex being nearly two and a half times as much as for the combed hairs. The variation, however, is not regular, the values for the right and the left flank being very nearly equal. Consequently, the value for either of the flanks may be taken for comparison with the other regions of the seed. From column 2 we next notice that the apical fibres are the most rigid, those from the flanks take the second place while those from the base are a close third. The combed hairs possess the lowest rigidity.

The frequency distributions and the statistical constants are given in Tables VII and VIII respectively.

TABLE VII

Frequency distribution of fibre rigidity (dynes cm² 10^{-2}): fibres from all regions of the seed, Nandyal 14

Group	Base	Apex	Right flank	Left flank	Combed hairs
0	18	6	8	5	38
1	28	11	22	13	47
2	25	19	34	38	20
3	21	29	37	36	23
4	19	26	16	23	10
5	10	20	11	21	4
6	16	12	12	8	3
7	5	12	4	2	3
8	2	7	5	3	2
9	1	4	3	1	
10	1	5	1		
11 etc. . . .	2	3			
TOTAL	148	154	153	150	150
Mean	3·11	4·42	3·31	3·32	1·91

TABLE VIII

Frequency constants for the frequency distributions of fibre rigidity: (10^{-2} dynes cm^2) fibres from all regions of the seed, Nandyal 14 Units.

Quantity	Base	Apex	Right flank	Left flank	Combed hair
Mean M	3·11	4·42	3·31	3·32	1·91
Q1	1·19	2·64	1·79	2·06	0·42
Q3	4·55	5·93	4·41	4·44	2·88
e_1	1·92	1·79	1·52	1·25	1·49
e_2	1·44	1·50	1·10	1·12	0·97
Q	1·68	1·64	1·31	1·19	1·23
E (S. O.)	1·64	1·72	1·43	1·15	1·18
[illegible]	2·44	2·55	2·12	1·71	1·75
Cv	78·3	57·6	64·1	51·7	91·9
CA	0·154	0·064	0·134	0·039	0·273
Skewness	0·513	0·528	0·595	0·418	0·976

Same notation as used in Table II.

TABLE IX

Mean fibre rigidity, Nandyal 14.

Region	Percentage of fibres in each region		Mean rigidity 10^{-2} dynes cm^2
	By weight	By number	
Base	30·0	30·0	3·11
Apex	16·0	17·3	4·42
Right flank	23·0	20·7	3·31
Left flank	24·0	22·7	3·32
Combed hairs	7·0	9·3	1·91
Straight mean			3·21
Weighted mean (by weight)			3·33
Weighted mean (by number)			3·32
Technological Reports (bulk mean)			3·03

The distributions for the right flank, the left flank and the combed hairs resemble closely those for the base and the apex in as much as they all deviate from normality, as shown by the trend of values given in Table VII and the relevant constants in Table VIII. Consequently, we are again unable to apply the standard error test for judging the significance of differences and will, as before, resort to the quartile test. It is not necessary to give the details of the application of this test. It may only be stated that on applying this test it is found that the differences between the flanks, and between the base and the flanks are not significant, while those between other regions of the seed are significant.

The percentage distribution by weight of fibres on different regions of the seed and the unit fibre weight pertaining to each region are given in another publication [Koshal and Ahmad, 1932]. From a knowledge of these two quantities we can readily calculate the percentage distribution *by numbers* of fibres on different regions of the seed. We can then proceed a step further and calculate the weighted mean, both according to distribution by weight and distribution by number, of the values from the apex, base, etc. These means together with the 'straight' mean and the value for the bulk sample taken from the *Technological Reports on Standard Indian Cottons* [Ahmad, 1931]

are given in Table IX. It will be seen that the two weighted means are very nearly equal to the 'straight' mean, showing that the effect of regional differences in rigidity is balanced to a large extent by the relative proportions of fibres on the surface of the seed. Again, the weighted means are only slightly higher than the mean for the bulk sample in spite of the large difference between the rigidities of the apical and the combed hairs. This is no doubt due to the relatively small number of the latter as compared with the remaining fibres on the seed, as also to the balancing effect of the high rigidity of the apical fibres with the low rigidity of the combed fibres.

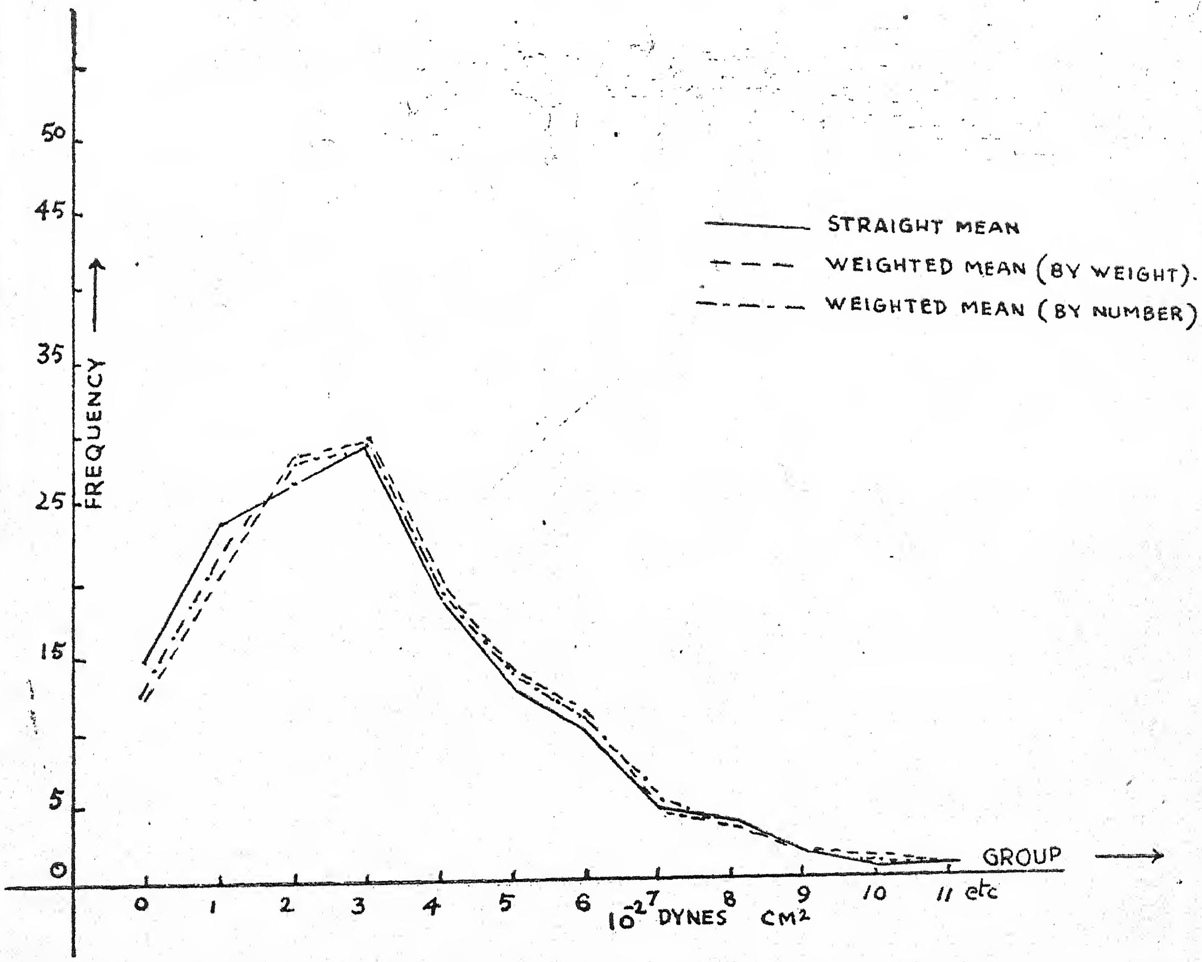

FIG. 2A. Frequency distribution of rigidity values for fibres of Nandyal 14.

The curves showing the frequency distributions of rigidity values for fibres from all regions of the seed of Nandyal 14 are given in Figs. 2A and 2B.

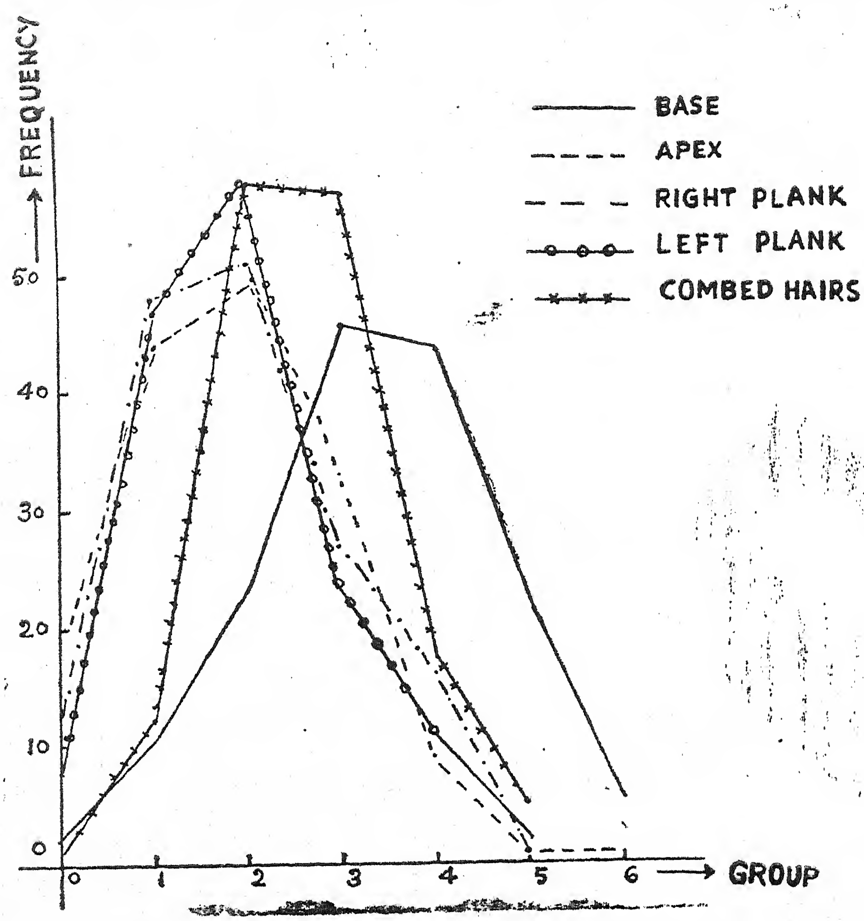

FIG. 2B. Frequency distribution of rigidity values for fibres of Nandyal 14.

It will be seen that these are of two distinct types, those for the basal and the combed hairs show definite J-shape tendency, while those for the other regions are model curves, which have deviated from the normal and are skew. The latter resemble the curves for fibre strength. The coefficient of asymmetry for these distributions given in Table VIII confirms this statement. This statistic is relatively small for the flanks and the apex as compared with that for the base.

In order to study the effect of the two types of distribution on the bulk sample, curves combining the values for all the five portions (both on the basis of the arithmetic and the weighted means) were drawn and superposed on the individual curves. The three curves utilising the mean values follow a similar course and lie fairly close to the curve for the basal fibres, which has a mild tendency towards J-shape. It is interesting to note that these curves are very similar in type to that indicated by Khosal and Turner [1930] for Nandyal 14, when a small number of fibres was tested. In fact, their classification of the eight cottons under test according to the shape of the frequency distribution polygon for fibre rigidity is similar to the classification given previously in this paper. This deviation from a definite J-shape, as obtained by Khosal and Turner for 1027 A. L. F., to a mere mild tendency towards J-shape, is very probably due to the preponderating influence of the skew distributions for the fibres from the flanks and the apex. The study of the results for Nandyal 14 shows that the rigidity curve obtained for a bulk sample is not a simple curve, but a combination of J and skew distributions superposed upon one another and arising from a mixture of the fibres from all

parts of the seed. The influence of the basal and the combed hairs is felt strongly in the curve for the bulk sample, which accordingly acquires a mild J-shape tendency. Such a variety in types of curves for the different constituents of the population, as in most cases the composite population itself showing a type of its own, herein studied is peculiar to fibre rigidity. From this point of view it may be useful to study other cottons which show strong differences in the types of curves for the bulk sample and its various constituents.

(c) *Probable effect of a J-distribution on Spinning.*

A J-distribution indicates the presence of a large percentage of fibres of low rigidity. Such fibres on account of their pliability and suppleness can be twisted with ease without straining the fibre. But these like the combed fibres are generally weak and immature lacking structural solidarity and promote nep formation. Fibres should therefore possess sufficient rigidity to prevent clustering but not to resist twisting.

Turner and Venkataraman [1933] have found a correlation of 0·58 between fibre strength and fibre rigidity. While fibre strength would contribute directly towards yarn strength, the same fibres being too rigid resist a spin thus affecting its spinning capacity. The low correlation between fibre strength and yarn strength as well as the negative correlation—0·33 [Turner and Venkataraman, 1933] between fibre strength and spinning value may be partly due to the opposing influences of the two positively related properties, fibre rigidity and fibre strength, on the spinning quality. Cottons with moderate values of rigidity and strength may prove better than those with extreme values.

RIBBON WIDTH

(a) *Base and apex.*

The frequency distribution of ribbon width for the basal and the apical fibres for the eight cottons tested are given in Table X. It will be noticed that the individual values are distributed over a fairly wide range in all cases.

TABLE X

Ribbon width—frequency distribution

—	Nandyal 14		P. A. 4F		C. A. 9 1928-29		C. A. 9 1929-30		Gadag I 1928-29		Gadag I 1927-28		Verum 262 (Nagpur)		Surat 1027 A. L. F.	
Group 10^{-4} cms.	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex
9	1								1							
10	1						1		2		3					
11	3				3	1	6		11	3	14	2	3	3		
12	4				2	10	12	7	25	4	27	3	2	5	1	
13	11	2	1		10	16	20	23	35	21	34	28	15	14	5	
14	19	6	2	1	19	23	33	27	37	31	32	28	22	17	7	1
15	27	9	5	0	39	40	29	36	16	24	26	34	23	38	14	6
16	21	19	8	4	35	27	24	29	15	36	9	32	20	28	21	13
17	22	20	8	8	23	18	14	23	7	20	7	11	21	10	22	13
18	14	28	12	10	9	11	4	7	3	15	2	9	28	17	27	23
19	15	29	26	23	4	4	3	2	2	1	1	4	9	7	16	27
20	9	22	27	30	2		2	1	0	4		3	4	2	21	20
21	6	8	20	25	1		0		1	1		1	8	3	4	18
22	0	6	17	20	1		2						2	2	10	12
23	2	3	17	20	0								1		6	7

TABLE X—*contd.*

Ribbon width—frequency distribution—contd.

——	Nandyal 14		P. A. 4F		C. A. 9 1928-29		C. A. 9 1929-30		Gadag I 1928-29		Gadag I 1927-28		Verum 262 (Nagpur)		S. 1027 A. L. F.	
Group 10-4 cms.	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex	Base	Apex
24		1	6	6	2										0	5
25		2	5	2											0	4
26			2	1											1	1
27																1
28																1
Total . . .	155	155	156	150	150	150	150	155	155	160	155	150	153	155	155	152

TABLE XI

Ribbon width 10^{-4} cm.—Mean values and frequency constants—base and apex

Cotton		Mean M.	$\frac{A-B}{B}$ 100	. .	Cv= $\frac{..}{M}$ × 100	Q_1	Q_3	e_1	e_2	$\frac{Q_3-Q_1}{2}$ =Q	E (S. O.)	$\frac{e_1-e_2}{M}$ =CA	Skewness
Nandyal 14 . .	B	16·26	12·5	2·569	15·8	14·54	18·07	1·72	1·82	1·77	1·734	—0·006	0·180
	A	18·29		2·283	12·5	16·69	19·70	1·60	1·41	1·50	1·540	0·010	—0·038
P. A. 4F. . .	B	20·15	2·0	2·597	12·9	18·67	22·02	1·49	1·87	1·68	1·75	—0·019	0·011
	A	20·56		2·103	10·2	19·18	22·12	1·38	1·57	1·47	1·419	—0·009	0·057
C. A. 9 (1928-29) .	B	15·77	—3·5	2·027	12·8	14·60	16·75	1·13	0·98	1·05	1·368	0·010	0·241
	A	15·20		1·735	11·4	14·01	16·38	1·20	1·18	1·19	1·170	0·001	0·052
C. A. 9 (1929-30) .	B	14·80	2·4	2·072	14·0	13·68	16·03	1·12	1·23	1·18	1·398	—0·075	0·207
	A	15·15		1·649	10·8	13·87	16·35	1·27	1·20	1·24	1·113	—0·045	0·049
Gadag I (1928-29) .	B	13·82	11·4	1·916	13·8	12·54	14·88	1·28	1·05	1·17	1·292	0·017	0·281
	A	15·39		1·910	12·4	13·94	16·60	1·45	1·21	1·33	1·288	0·015	—0·059
Gadag I (1927-28) .	B	13·64	11·7	1·744	12·8	12·36	14·79	1·28	1·15	1·22	1·177	0·104	0·175
	A	15·23		1·837	12·1	13·89	16·25	1·34	1·02	1·18	1·239	0·029	0·198
Verum 262 (Nagpur) .	B	16·17	—2·4	2·321	14·4	14·38	17·86	1·79	1·69	1·74	1·566	0·007	0·064
	A	15·79		2·133	13·5	14·53	17·14	1·26	1·35	1·30	1·439	—0·006	0·315
1027 A. L. F. . .	B	17·94	9·0	2·556	14·2	16·11	19·70	1·83	1·76	1·80	1·724	0·004	0·132
	A	19·55		2·628	13·4	17·78	21·16	1·78	1·61	1·70	1·773	0·009	0·296

B=Base. A=Apex
Same notation as used in Table II.

The mean values and the statistical constants calculated for these distributions are given in Table XI. Considering the mean values given in Column 2 of Table XI, it is found that with the exception of C. A. 9 (1928-29) and Verum 262, the mean ribbon width of the apical fibres is higher than that of the basal fibres.

Though these differences ranging from 2·0 to 12·5 per cent (in terms of the basal fibres) are not large, the cottons can be classified into two groups (1) Nandyal 14, Gadag I and 1027 A. L. F. for which the difference is nearly equal and relatively large ranging from 9·0 to 12·5 per cent and (2) P. A. 4F, C. A. 9 and Verum 262, for which again the difference is nearly equal but small ranging from 2·0 to 3·5 per cent only. It may be noted that the two exceptions mentioned above, viz. C. A. 9 (1928-29) and Verum 262, for which the basal fibres have a larger ribbon width, come in the second group.

As these differences are not only small in magnitude but vary in direction from cotton to cotton it would be necessary to examine statistically if they are beyond errors of random sampling. The necessity for such criterion becomes evident when it is seen that while the coefficient of variation ranging from 10·2 to 15·5 per cent is small and does not differ appreciably either from cotton to cotton or from region to region, it is greater than the percentage difference between the two regions. In the case of the cottons of the second group the regional difference is less than even twice the standard deviation.

The exact statistical test to be employed depends on the frequency distribution of ribbon width in the samples. An inspection of the frequency polygons drawn in Fig. 3, shows that the distributions are more or less normal, this can also be seen from the statistical constants given in Table XI which show that the values of e_1, e_2, Q and E (S. O.) are fairly close together for each distribution. Moreover the coefficient of asymmetry and skewness are fairly small ranging from 0·001 to 0·104 and from 0·011 to 0·315 respectively. It is therefore proposed to apply Fisher's t test to judge the significance of differences in mean value between the two regions for a cotton.

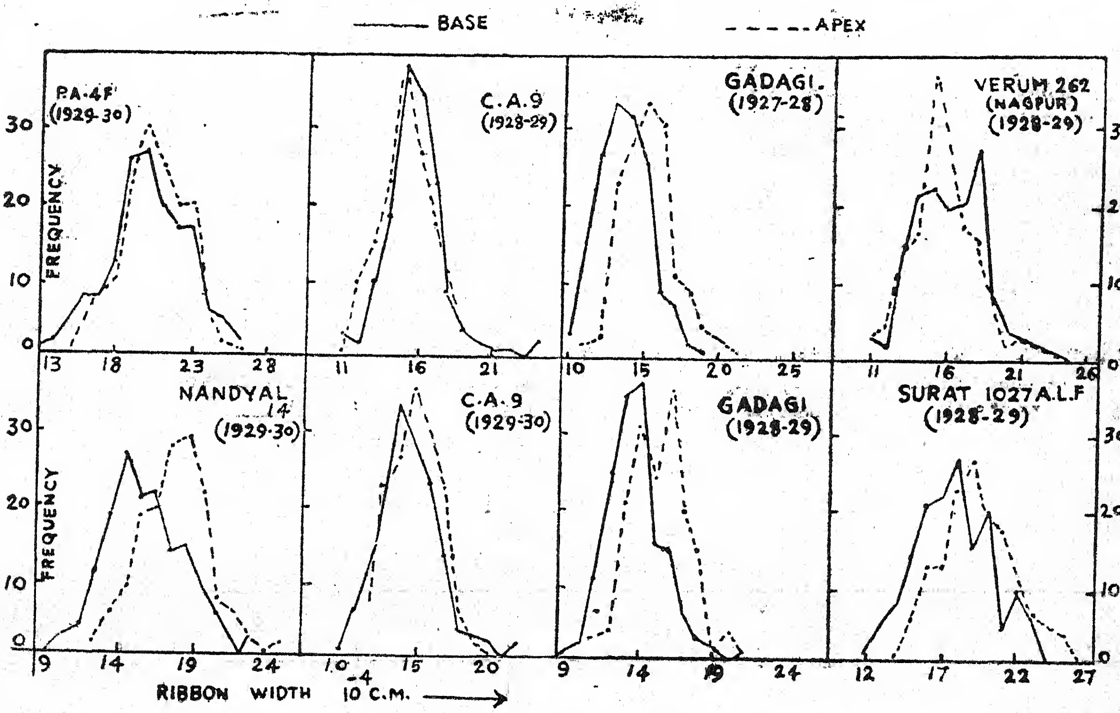

FIG. 3. Frequency Polygons.

The necessary data are calculated and given in Table XII.

TABLE XII

Ribbon width 10^{-4} cm. : Significance of differences—base and apex

No.	Cotton	Base B	Apex A	A-B	n	t	p	Remarks
1	Nandyal 14	16·26	18·29	2·03	308	8·31	<0·01	Significant
2	P. A. 4F.	20·15	20·56	0·41	304	1·49	0·1 to 0·2	Not significant
3	C. A. 9 (1928-29)	15·77	15·20	—0·57	298	2·58	<0·01	Significant
4	C. A. 9 (1929-30)	14·80	15·15	0·35	303	1·51	0·1 to 0·2	Not significant
5	Gadag I (1928-29)	13·82	15·39	1·57	313	7·22	<0·01	Significant
6	Gadag I (1927-28)	13·64	15·23	1·59	303	7·73	<0·01	Significant
7	Verum 262	16·17	15·79	—0·38	306	1·50	0·1 to 0·2	Not significant
8	1027 A. L. F.	17·94	19·55	1·61	305	5·42	<0·01	Significant

The remarks in the last column agree with the earlier conclusion that the cottons can be classified into two groups (1) Nandyal 14, Gadag I and 1027 A. L. F., for which the differences are significant and the apical fibres are broader and (2) Verum 262, and P. A. 4F for which the regional difference is negligible. C. A. 9 however is an exception for the difference between the apical and basal fibres is not only significant but, unlike other cottons, the apical fibres in the season 1928-29 have also a smaller width. But the sample for the season 1929-30 reveals no significant regional difference.

These conclusions are also supported by the frequency polygons given in Fig. 3 wherein the curves for the two regions nearly overlap in the case of P. A. 4F, C. A. 9 and Verum 262, while in the case of Nandyal 14, Gadag I and 1027 A. L. F. the curves for basal fibres shifted to the right would give approximately the curve for the apical fibres.

It is therefore concluded that while the ribbon width of the apical and the basal fibres is nearly the same for the cottons P. A. 4F, C. A. 9 and Verum 262, the fibres of the apical region have a larger ribbon width for the cottons Nandyal 14, Gadag I and 1027 A. L. F.

The shape of the frequency polygons may now be considered. From the curves drawn in Fig. 3 and from the statistical constants given in Table XI, it is concluded that these distributions in the two regions do not deviate much from the normal for any of these cottons.

TABLE XIII

Ribbon width 10^{-4} cm. base and apex

Cotton	Base	Apex	Technological Reports (bulk)
Nandyal 14	16·26	18·29	16·52
P. A. 4F.	20·15	20·56	17·53
C. A. 9 (1928-29)	15·77	15·20	15·24
C. A. 9 (1929-30)	14·80	15·15	16·26
Gadag I (1928-29)	13·82	15·39	15·00
Gadag I (1927-28)	13·64	15·23	15·75
Verum 262 (Nagpur)	16·17	15·79	15·75
1027 A. L. F.	17·94	19·55	18·05

In Table XIII the mean ribbon width of the basal and apical fibres as well as the mean for the bulk sample taken from the *Technological Reports* [Ahmad, 1931] are given for comparison. It is noticed therefrom that unlike the similarity between samples from the bulk and the different regions observed in regard to the frequency distribution, the mean for the bulk does not disclose any uniform relationship with either the basal or the apical fibres as was found in the case of fibre rigidity, probably due to the influence of the fibres from the flanks and the combed fibres which may have a different mean value as in the case of Nandyal 14 discussed later.

Seasonal variations. As in the case of rigidity only two cottons Gadag I and C. A. 9 were tested for two different seasons. From the Tables XI and XII it is seen that for C. A. 9 tested for 1928-29 and 1929-30 the difference in ribbon width between the two regions is small being — 3·5 per cent and 2·4 per cent only in the respective seasons, but positive though not significant in the latter and negative but significant in the former season. For Gadag I tested for 1928-29 and 1927-28, however the ribbon width of the apical fibres is greater than that of the basal fibres by 11·4 per cent and 11·7 per cent respectively in the two seasons and both are significant.

This indicates that while the effect of season of growth on the relative difference in ribbon width between the basal and apical fibres is generally in appreciable, some cottons may give a differential response to season of growth.

(*b*) *Fibres from all regions of the seed*

The tests again are confined to only one cotton, viz. Nandyal 14. The mean ribbon width of fibres from all the five regions as well as the difference between one region and another, calculated as a percentage of the lower value in each case, are given in Table XIV.

TABLE XIV

Ribbon width 10^{-4} cm.: Significance of regional differences (fibres from all regions of the seed surface) —Nandyal 14

No.	Region	Mean	Difference between	Difference	Percentage difference	n	t	p	Remarks
1	2	3	4	5	6	7	8	9	10
1	Base (B)	16·26	B-A	—2·03	—12·5	308	8·31	<0·01	Significant
2	Apex (A)	18·29	B-R	—1·18	—7·3	308	4·05	<0·01	Significant
3	Right flank (R)	17·44	B-L	—1·37	—8·4	303	5·13	<0·01	Significant
4	Left flank (L)	17·63	B-C	—2·86	—17·6	304	9·78	<0·01	Significant
5	Combed fibres (C)	19·12	A-R	0·85	4·9	308	3·12	<0·01	Significant
6	Arithmetic mean	17·75	A-L	0·66	3·7	303	2·66	<0·01	Significant
7	Weighted mean	17·41	A-C	—0·83	—4·5	304	3·02	<0·01	Significant
8	Technological Reports: Bulk mean	16·52	R-L	—0·19	—1·1	303	0·74	0·4 to 0·5	Not significant
			R-C	—1·68	—9·6	304	5·86	<0·01	Significant
			L-C	—1·49	—8·5	299	5·63	<0·01	Significant

It is seen therefrom that the combed hairs have the maximum ribbon width, the apical, the right and the left flanks, and the basal fibres following in order. The maximum difference in ribbon width which is between the basal and the combed fibres is 17·6 per cent and the minimum of 1·1 per cent is between the two flanks. Most of these differences are small and as such tests of significance are necessary.

The frequency distributions and the statistical constants are given in Tables XV and XVI respectively.

TABLE XV

Frequency distribution of ribbon width 10^{-4} cm., Nandyal 14

Group	Base	Apex	Right flank	Left flank	Combed fibres
9	1				
10	1				
11	3				
12	4		4	1	1
13	11	2	6	1	0
14	19	6	8	7	3
15	27	9	12	14	6
16	21	19	29	19	15
17	22	20	27	28	18
18	14	28	22	38	19
19	15	29	15	17	24
20	9	22	14	18	20
21	6	8	11	2	24
22	0	6	2	3	6
23	2	3	3	0	9
24		1	1	1	2
25		2	1	1	3
26					1
27					
28					
Total No. of fibres	155	155	155	150	151
MEAN	16·26	18·29	17·44	17·63	19·12

TABLE XVI

Frequency constants for the frequency distributions of ribbon width 10^{-4} cm.: fibres from all regions of the seed surface Nandyal 14

Constants	Base	Apex	Right flank	Left flank	Combed hairs
Mean M	16·26	18·29	17·44	17·63	19·12
f.	2·569	2·283	2·510	2·027	2·529
C. V.	15·8	12·5	14·4	11·5	13·2
Q_1	14·54	16·69	15·85	16·31	17·26
Q_3	18·07	19·70	19·10	18·81	20·85
e_1	1·72	1·60	1·59	1·32	1·86
e_2	1·82	1·41	1·66	1·18	1·73
Q	1·77	1·50	1·62	1·25	1·80
E (S. O.)	1·734	1·540	1·693	1·368	1·706
C_A	—0·006	0·010	—0·004	0·007	0·007
Skewness	0·189	—0·038	0·328	—0·076	0·078

(Same Notation as used in Table II).

It will be observed therefrom that as before, the t test can be applied to judge the significance of these regional differences in ribbon width. The relevant data are calculated and given in Table XIV from which it is concluded that except between the right and left flanks the difference between every other region is significant. The fibres on the two flanks have practically the same ribbon width.

The combed fibres have the maximum width probably caused by a premature detachment from the seed coat and consequent deficiency in cell wall development whereby it is flattened when the fibres collapse on boll ripening.

The apical fibres come next in order. As will be shown later the apical fibres, though narrower than the combed fibres, have in all probability a greater wall thickness than the latter, which are perhaps immature. Ribbon width would thus be an inadequate measure of fineness of a cotton as one with a larger width may be finer though weaker, being thin walled, than another with less width but greater wall thickness.

The fibres from the flanks, very similar between themselves, have a smaller width than the apical but larger than the basal fibres which, however, have the minimum width.

The mean value for the bulk sample as given in the *Technological Reports* [Ahmad, 1931] as well as the straight and weighted means calculated from the average values for the different regions are given in Table XIV. It is seen that the arithmatic mean and the weighted mean are nearly the same and slightly higher than the mean for the bulk which, however, corresponds to the mean ribbon width of the basal fibres.

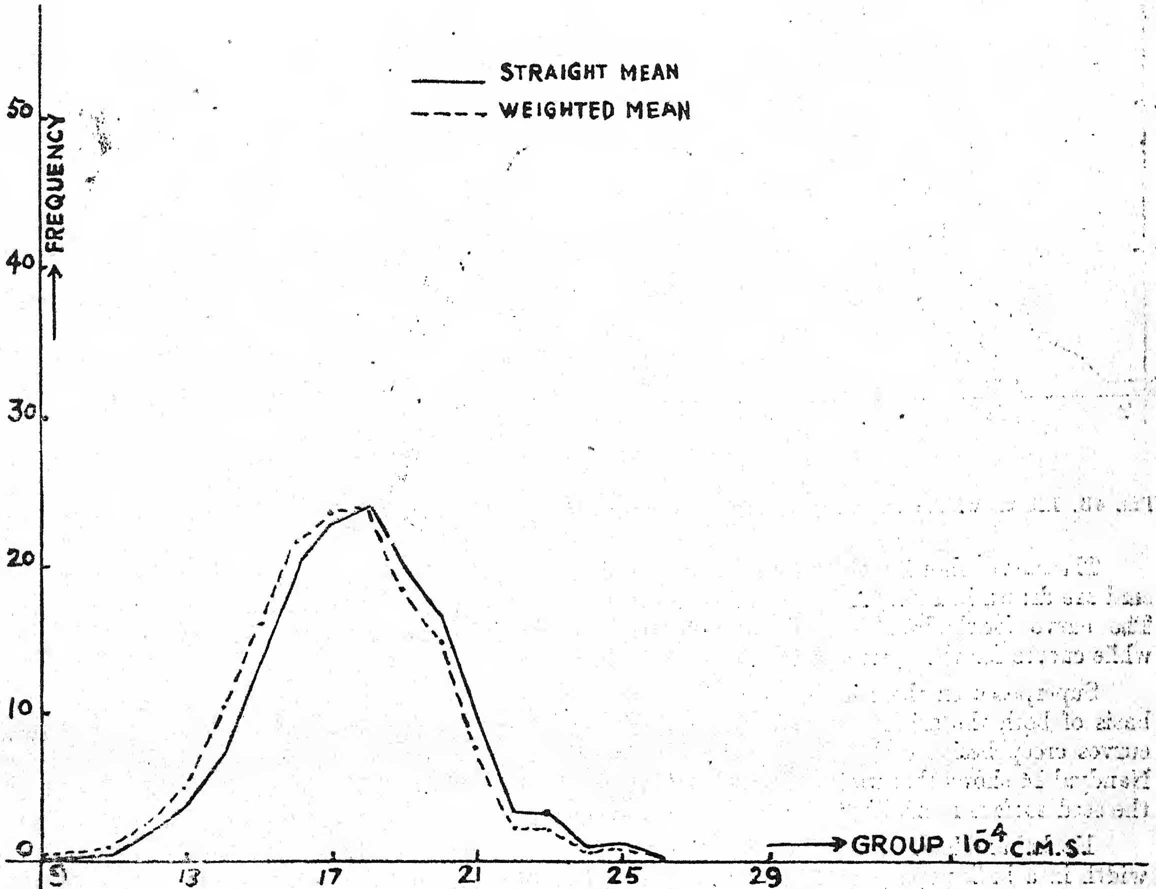

FIG. 4A. Ribbon width: Frequency distribution curves; fibres from all regions of the seed, Nandyal 14

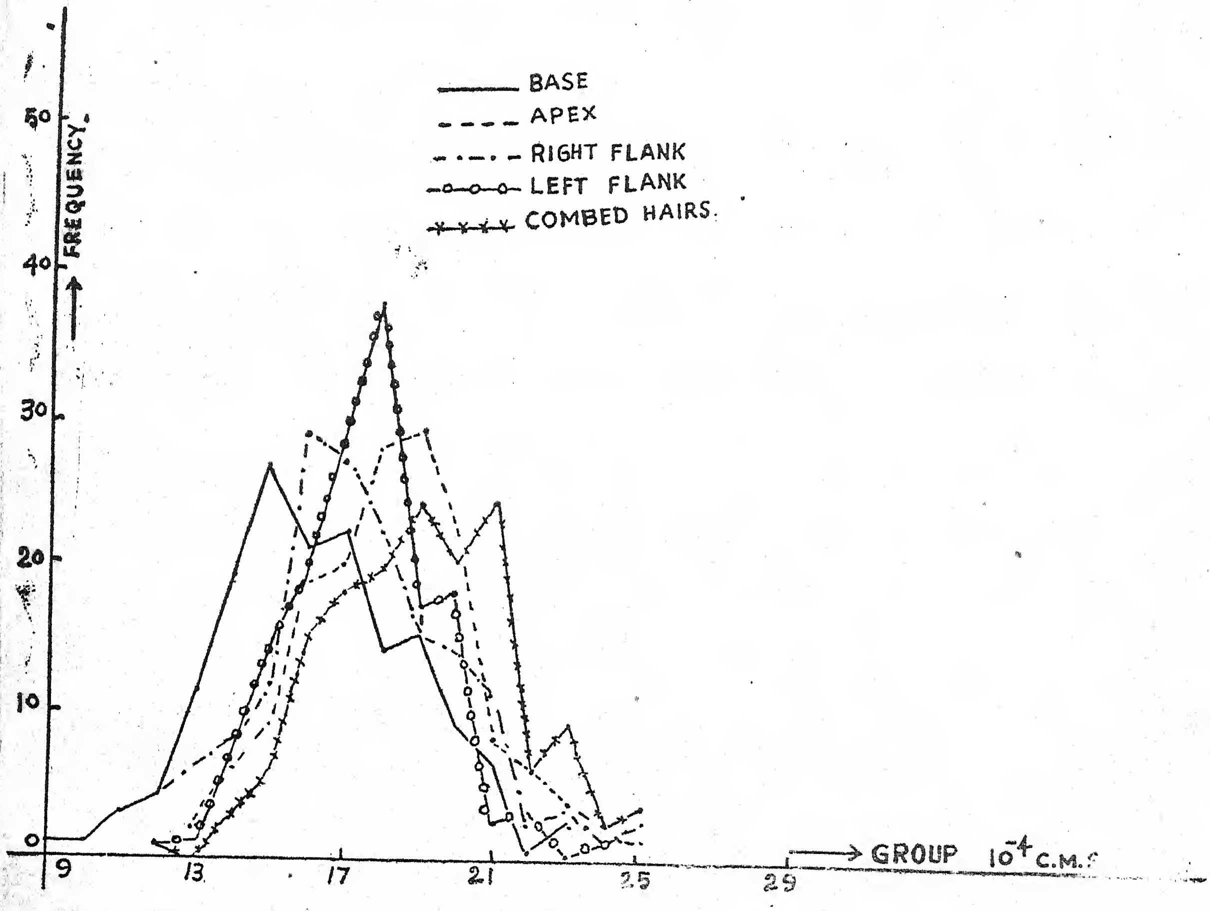

FIG. 4B. Ribbon width: Frequency distribution curves; fibres from all regions of the seed, Nandyal 14

The curves showing the frequency distribution of ribbon width for fibres from all regions of the seed are drawn in Figs. 4A and B. All the curves are similar and more or less normal in shape. The curve for the basal fibres lies more towards the left while that for the combed fibres to the right while curves for the apex and the flanks lie in between.

Superposed on these is the curve drawn by combining the values for all the five regions, on the basis of both the arithmatic and the weighted means, to give the bulk sample pattern. The two curves creep beside each other and both are nearly normal shaped. A study of these curves for Nandyal 14 shows that unlike the case of fibre rigidity not only is the distribution for each region of the seed surface normal but also for the bulk sample composed of fibres from these different regions.

Koshal and Turner [1930] after testing 3000 fibres have concluded that the distribution of ribbon width in a bulk population is normal. The present results show that this is true not only for the whole population but also for its constituent elements, i.e. even when fibres from individual regions of the seed are tested. Such a distribution therefore must be an inherent quality of fibre development on any part of the seed and is not just a result of the mixture of fibres from various regions of a seed or from various seeds. This result contrasts with the results for fibre rigidity in which case the distributions in the different regions were dissimilar.

Convolutions

(*a*) *Base and apex*

The frequency distribution of the number of convolutions per mm. for the basal and the apical fibres are given in Table XVII for the eight cottons tested.

TABLE XVII

Frequency distribution of convolutions per mm. : Base and apex

Group	Nandyal 14		P. A. 4F.		C. A. 9 (1928-29)		C. A. 9 (1929-30)		Gadag I (1928-29)		Gadag I (1927-28)		Verum 262 (Nagpur)		1027 A. L. F.	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
0	2	18	0	0	0	0	0	0	0	0	0	0	2	4	0	1
1	11	44	12	0	1	2	2	6	0	0	0	4	2	24	3	18
2	24	49	17	4	9	11	10	29	6	6	6	16	17	38	29	72
3	46	33	37	33	21	27	14	39	15	27	14	32	28	31	71	49
4	44	9	37	38	25	41	28	35	23	48	15	38	59	37	40	11
5	22	1	34	50	25	38	30	29	36	42	39	38	28	14	10	1
6	6	1	13	16	26	25	28	11	42	24	38	14	9	7	2	0
7			5	8	19	4	23	4	23	11	29	5	6	0		
8			1	1	20	2	10	2	6	2	9	3	2	0		
9					4	0	4	0	4	0	4	0				
10							1	0			1	0				
Total	155	155	156	150	150	150	150	155	155	160	155	150	153	155	155	152

B=Base ; A=Apex

The statistical constants for these distributions are calculated and given in Table XVIII.

TABLE XVIII

Frequency constants for the frequency distribution of the number of convolutions per mm. : Base and apex

1		2	3	4	5	6	7	8	9	10	11	12	13
Cotton		Mean M	$\frac{A-B}{B}\times100$	σ	$\frac{\sigma}{M}\times100=$ =Cv	Q_1	Q_3	e_1	e_2	$\frac{Q_3-Q_1}{2}$ =Q	E (S. O.)	$\frac{e_1-e_2}{M}$ =CA	Skewness
Nandyal 14	B	3·40	—43·3	1·276	37·5	2·55	4·21	0·85	0·80	0·83	0·86	0·012	—0·692
	A	1·93		1·123	58·1	1·02	2·71	0·91	0·78	0·84	0·76	0·069	0·173
P. A. 4F	B	3·87	16·6	1·513	39·1	2·82	4·96	1·05	1·09	1·07	1·02	—0·011	—0·008
	A	4·51		1·196	26·5	3·56	5·30	0·95	0·79	0·87	0·81	0·035	—0·100
C. A. 9 (1928-29)	B	5·33	—17·5	1·904	35·7	3·81	6·84	1·52	1·51	1·51	1·28	0·002	0·031
	A	4·40		1·361	30·9	3·46	5·38	0·95	0·98	0·96	0·92	—0·007	0·220
C. A. 9 (1929-30)	B	5·26	—28·3	1·829	34·8	3·96	6·57	1·30	1·32	1·31	1·23	—0·004	0·011
	A	3·77		1·480	39·3	2·65	4·80	1·12	1·03	1·08	1·00	0·023	0·235

TABLE XVIII

Frequency constants for the frequency distribution of the number of convolution per mm. : Base and apex

1	2		3	4	5	6	7	8	9	10	11	12	13
Cotton	Mean M		$\frac{A-B}{B}\times 100$	σ	$\frac{\sigma}{M}\times 100 = Cv$	Q_1	Q_3	Q_1	Q_2	$\frac{Q_1-Q_2}{2}=Q$	E (S. O.)	$\frac{c_1-c_2}{M}=0$	Skewness.
Gadag I (1928-29)	B	5·38	—14·1	1·554	28·9	4·32	6·41	1·06	1·03	1·05	1·05	0·004	—0·003
	A	4·62		1·296	28·0	3·70	5·48	0·93	0·85	0·89	0·87	0·016	0·222
Gadag I (1927-28)	B	5·59	—25·6	1·621	29·0	4·65	6·70	0·94	1·11	1·03	1·09	—0·031	—0·105
	A	4·16		1·459	35·0	3·05	5·14	1·12	0·98	1·05	0·98	0·033	0·017
Verum 262 (Nagpur)	B	4·03	—26·1	1·387	34·4	3·17	4·79	0·86	0·76	0·81	0·91	0·024	0·023
	A	2·98		1·443	48·4	1·83	4·07	1·14	1·09	1·12	0·97	0·017	0·117
1027 A. L. F.	B	3·25	—25·9	0·963	29·6	2·65	3·88	0·60	0·63	0·62	0·65	—0·008	0·185
	A	2·41		0·829	39·8	1·81	3·02	0·59	0·61	0·60	0·56	—0·008	0·235

B=Base ; A=Apex

The notation is the same as used in Table II

From column 3 of Table XVIII, in which the percentage mean differences in convolutions per mm. between the two regions calculated in terms of the basal fibres are given, it is observed that except in the case of P. A. 4F. the basal fibres have a greater number of convolutions per mm. than the apical, the difference ranging from 14·1 per cent for Gadag I(1928-29) to 43·3 percent for Nandyal 14. For P. A. 4F., however, the apical fibres have 16·6 per cent more number of convolutions per mm. The difference in seven cases ranges between 14·1 per cent and 28·3 per cent and it is 43·3 per cent only for the one remaining cotton, Nandyal 14. Since the coefficient of variation is fairly high ranging from 28·0 per cent to 58·1 per cent and greater than the percentage differences in mean values, the significance of the differences must, as before, be ascertained by statistical tests.

Since an inspection of the frequency polygons drawn in Fig. 5 and the statistical constants given in Table XVIII show that the distributions are approximately normal, Fisher's method of variance (Z test) will be applied.

The relevant data are calculated and the results given in Table XIX.

TABLE XIX

Convolutions per mm. : Significance of differences : Base and apex (Method of variance)

Cotton	Base (B)	Apex (A)	A-B	n_1	n_2	Z	Z for P=·01 for $n_1=1$ & $n_2=\infty$	Remarks
Nandyal 14	3·40	1·93	—1·47	1	308	2·37	0·95	Significant
P. A. 4F.	3·87	4·51	0·64	1	304	1·41	0·95	,,
C. A. 9 (1928-29)	5·33	4·40	—0·93	1	298	1·58	0·95	,,
C. A. 9 (1929-30)	5·26	3·77	—1·49	1	303	2·03	0·95	,,
Gadag I (1928-29)	5·38	4·62	—0·76	1	313	1·54	0·95	,,
Gadag I (1927-28)	5·59	4·16	—1·43	1	303	2·05	0·95	,,
Verum 262	4·03	2·98	—1·05	1	306	1·82	0·95	,,
1027 A. L. F.	3·25	2·41	—0·84	1	305	2·10	0·95	,,

It is seen therefrom that the differences are significant in all the cases even including that of P. A. 4F., which has given results contrary to others.

It is therefore concluded that with the exception of P. A. 4F. the convolutions in the apical fibres are more widely spaced than in the basal fibres. For P. A. 4F. however, the convolutions are more crowded in the apical fibres. For C. A. 9 (1929-30), Gadag I (1927-28), Verum 262 and 1027 A. L. F. the relative difference between the two regions is practically same, ranging between 25·6 per cent and 28·3 per cent only.

While the results of the number of convolutions per mm. were considered so far, those of the total number of convolutions *per fibre* may now be taken up.

In Table XX the number of convolutions per fibre for the basal and the apical regions are given along with the percentage differences between the regions in the case of each cotton.

TABLE XX

Convolutions per fibre: Mean values and percentage differences—base and apex

Cotton	Base B	Apex A	$\frac{A-B}{B} \times 100$
Nandyal 14	71	36	—49·2
P. A. 4F.	76	82	7·8
C. A. 9 (1928-29)	110	78	—29·1
C. A. 9 (1929-30)	108	68	—37·0
Gadag I (1928-29)	98	79	—19·4
Gadag I (1927-28)	107	74	—30·8
Verum 262 (Nagpur)	81	52	—35·8
1027 A. L. F.	68	49	—27·9

It is seen therefrom that with the exception again of P. A. 4F the number of convolutions is always greater for fibres from the base than the apex, the difference ranging between 19·4 per cent and 37·0 per cent only in all cases except Nandyal 14 for which it is 49·2 per cent. In the case of P. A. 4F, however, the apical fibres have 7·8 per cent greater number of convolutions. It appears, therefore, that in a good number of the cases considered the basal fibres have about 25 to 30 per cent greater number of convolutions than the apical fibres, though for Nandyal 14 the difference is nearly 50 per cent; for P. A. 4F, however, the apical fibres are more convoluted. These results are generally in accordance with the conclusions of Winters and Chaney [1924] that 'Increased density of hair population on the cotton seed coat is definitely associated with increased number of convolutions per inch', as the number of convolutions both per unit length, and per fibre, are generally greater for the basal fibres which are more densely distributed on the seed. But their further conclusions 'That increased length was found to be associated with decrease in the number of convolutions per inch', is not substantiated by these results as the apical fibres with a smaller mean length are less convoluted both per fibre and per unit length. The influence of these regional differences on the mean of a bulk sample can be seen from Table XXI, in which the means for both the apical and the basal fibres as well as the mean for the bulk taken from the *Technological Reports* [Ahmad, 1931], are given.

TABLE XXI

Convolutions per cm.: Comparative Values: Base, apex and Technological Reports

Cotton	Base	Apex	Technological Reports (bulk)
Nandyal 14	34	19	27
P. A. 4F.	39	45	42
C. A. 9 (1928-29)	53	44	50
C. A. 9 (1929-30)	53	38	43
Gadag I (1928-29)	54	46	48
Gadag I (1927-28)	56	42	45
Verum 262 (Nagpur)	40	30	28
1027 A. L. F.	32	24	25

It is seen therefrom that except for Verum 262, in other cases, the mean for the bulk lies between that for the base and the apex though nearer the latter for five cottons including Verum 262. This is due, judging from the results for Nandyal 14 discussed later, to the fact that for 75 per cent of the fibres on a seed comprising those from the apex, the flanks and the combed fibres, the mean value is nearly equal to that for the apical fibres but less than that for the basal fibres.

Considering together the regional differences both as regards convolutions and ribbon width discussed earlier, some interesting results are obtained. Denham [1923] states 'That Miss. G.G. Clegg of this Laboratory has shown that the ratio of ribbon width to wall thickness is directly correlated with the number of convolutions per unit length'. The present tests have revealed that generally the apical fibres have a greater width and smaller number of convolutions, which therefore indicate that the wall thickness of the apical fibres is greater. The relatively higher fibre weight and greater fibre strength found for the apical fibres by Koshal and Ahmad [1932] also point to the same conclusion. Further the same result is arrived at by calculating the value of $\bar{L}\times\sqrt{\rho}$ ($\bar{L}$=mean length and ρ=hair rigidity) which according to Peirce [1924] is 'a good measure of the degree of thickening'. The relevant data for all the eight cottons are calculated and given in Table XXII.

TABLE XXII

Product of hair rigidity and mean length: Base and apex

Cotton	Mean length $\bar{L}$ (cm)*		Mean hair rigidity 10^{-2} Dynes cm^2		$\bar{L}\sqrt{\bar{\rho}}$=S		δ= S_B-S_A
	Base	Apex	Base	Apex	Base (S_B)	Apex (S_A)	
Nandyal 14	2·46	1·93	3·11	4·42	4·34	4·06	0·28
P. A. 4F.	2·03	1·70	1·97	5·06	2·85	3·82	—0·97
C. A. 9 (1928-29)	2·34	1·98	3·26	4·55	4·23	4·22	0·01
C. A. 9 (1929-30)	2·28	1·90	2·82	3·89	3·83	3·75	0·08
Gadag I (1928-29)	2·03	1·80	2·00	4·77	2·87	3·93	—1·06
Gadag I (1927-28)	2·06	1·83	1·99	5·64	2·91	4·35	—1·44
Verum 262 (Nagpur)	2·08	1·83	4·17	8·77	4·25	5·42	—1·17
1027 A. L. F.	2·34	2·11	3·00	6·66	4·05	5·44	—1·39

*$\bar{L}$ is taken from the investigations by Koshal and Ahmad [1932] Table VI and converted into metric units; ρ is taken from Table II col. 4 of this paper.

It is seen therefrom that for five cottons the value of the product is much higher for fibres from the apex than the base. For C. A. 9 of both the seasons, the difference is negligible. Only in the case of Nandyal 14, the basal fibres show a higher value.

It can therefore be concluded that the apical fibres generally have a greater degree of thickening of the cell wall than the basal fibres.

Seasonal variations. As in other cases the results of only two cottons C. A. 9 and Gadag I are available for two different seasons. From Tables XVIII and XIX it is found that season of growth has no appreciable effect on the number of convolutions *per mm.* in a given region of the seed for either cotton, except for the apical fibres of C. A. 9 for which the sample for 1928-29 has a greater number than for 1929-30. While the basal fibres in any one season have a greater number of convolutions *per mm.*, the relative percentage difference between the regions slightly varies with season, being lower for the 1928-29 sample and higher for the sample of the other season for both cottons.

It may, however, be noted from Table XX that except for the basal fibres of C. A. 9 the mean number of convolutions *per fibre* as well as their relative difference between the regions varies with season of growth.

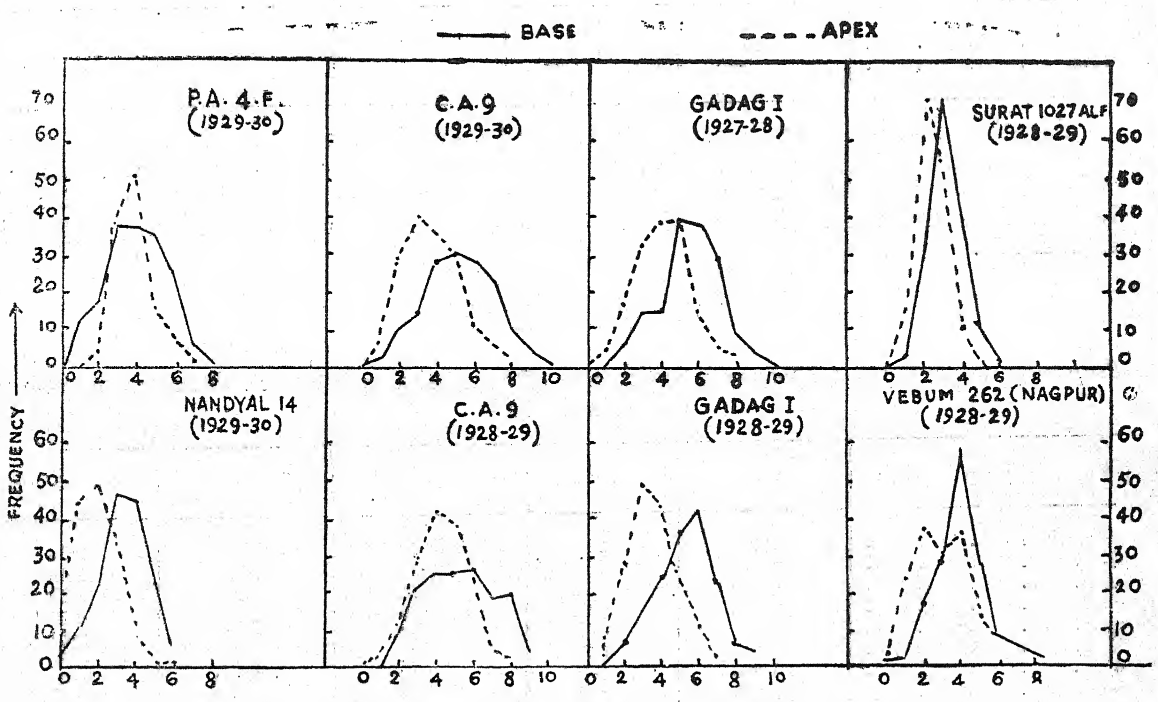

FIG. 5. Frequency Polygons: Convolutions per m^m^. ——→

The frequency polygons for the distributions given in Table XVII are drawn in Fig. 5. It is seen that the form of the curve is nearly the same for all cottons for the two regions and is nearly normal. In many cases like Nandyal 14, Gadag I and 1027 A. L. F. a lateral shift of the curves for apical fibres in the positive direction along the X-axis will nearly fit the curves for the basal fibres, showing that the form of distribution is typical irrespective of the variety of cotton or the region of origin. The statistical constants given in Table XVIII, viz. e_1, e_2, Q, E (S. O.), C_A and skewness also support this observation. Koshal and Turner [1930] have shown that in a bulk sample the convolutions are so distributed as to depart very little from normal. The present investigation shows that this is true not only for the sample as a whole but also for fibres on different regions of the seed surface which ultimately compose the bulk.

(*b*) *Fibres from all regions of the seed.*

TABLE XXIII

Frequency distribution of the number of convolutions per mm.—base, apex, right flank, left flank and combed fibres, Nandyal 14

Group	Base	Apex	Right flank	Left flank	Combed hairs
0	2	18	12	8	1
1	11	44	48	47	12
2	24	49	51	58	58
3	46	33	27	24	57
4	44	9	16	11	18
5	22	1	1	2	5
6	6	1			
Total	155	155	155	150	151
Mean	3·40	1·93	2·00	1·99	2·68

As before, the fibres from different regions are tested for only one cotton, viz. Nandyal 14.

The frequency distribution of the number of convolutions per mm. for fibres from the different regions of the seed surface, base, apex, right and left flanks, and the combed fibres are given in Table XXIII. The mean values and the statistical constants for these distributions are given in Table XXIV.

TABLE XXIV

Frequency constants for the frequency distribution of convolutions per mm.: Fibres from all regions: Nandyal 14

—	Base	Apex	Right flank	Left flank	Combed hairs
Mean M	3·40	1·93	2·00	1·99	2·68
Q_1	2·55	1·02	1·11	1·18	1·98
Q_3	4·21	2·71	2·74	2·54	3·29
e_1	0·85	0·91	0·89	0·81	0·70
e_2	0·80	0·78	0·74	0·55	0·61
Q	0·83	0·84	0·82	0·68	0·66
σ	1·276	1·121	1·101	1·030	0·933
E (S. O.)	0·860	0·757	0·742	0·695	0·629
Cv	37·5	58·1	55·0	51·9	34·8
CA	—0·012	0·069	0·075	0·128	0·023
Skewness	—0·069	0·173	0·294	0·269	0·150
Convolutions per fibre	71	36	44	45	51

Same Notation as in Table II

Considering the mean values it is seen that the number of convolutions per mm. differs from region to region, the basal fibres having the maximum number of 3·40 per mm., and the apical fibres the minimum of 1·93 per mm. The fibres from both the flanks have almost the same number of convolutions per mm., viz. 2·00 and 1·99, differing little from the apical fibres. The combed hairs have an intermediate value of 2·68 per mm. The fibres may thus be divided into three groups—basal, combed and rest—in descending order of average number of convolutions per mm.

As before, the mean values, percentage differences between any two regions calculated on the basis of the lower value, and the significance of these differences obtained by applying the method of variance (Z test), are given in Table XXV.

TABLE XXV

Convolutions per mm.: Significance of Differences: All regions of the seed: Nandyal 14—method of variance

Region	Mean	Difference between	Difference	Percentage difference	n_1	n_2	Z	Z for P=·01 $n_1=1$ & $n_2=\infty$	Significance
Base (B)	3·40	B-A	1·47	76·2	1	308	2·37	0·95	Significant
Apex (A)	1·93	B-R	1·40	70·0	1	308	2·33	0·95	Significant
Right flank (R)	2·00	B-L	1·41	70·9	1	303	2·36	0·95	Significant
Left flank (L)	1·99	B-C	0·72	26·9	1	304	2·60	0·95	Significant
Combed hairs (C)	2·68	A-R	—0·07	3·6	308	1	0·61	4·38*	Not significant
		A-L	—0·06	3·1	303	1	0·81	4·38*	Not significant
		A-C	—0·75	38·9	1	304	1·84	0·95	Significant
		R-L	—0·07	3·5	303	1	2·19	4·38*	Not significant
		R-C	—0·68	34·0	1	304	1·99	0·95	Significant
		L-C	—0·69	34·7	1	299	1·81	0·95	Significant

* Z for $n_1=\infty$ and $n_2=1$, for P=0·01

It is found therefrom that except for fibres between the two flanks, and between the apex and the flanks the other regional differences are significant. It is therefore concluded that the basal fibres come first with a maximum number of convolutions per mm. the combed fibres next with a smaller number, while the fibres from the apex and the two flanks come last and have practically the same number of convolutions per mm.

Convolutions per fibre: All regions of the seed. In Table XXIV the mean number of convolutions per fibre have been given for each of the five regions. Here again it is seen that the basal fibres with 71 twists are most convoluted and the apical fibres the least with 36 twists. The combed fibres again occupy an intermediate position. As regards the fibres from the two flanks while they have practically the same value, it is however less than for the combed fibres but more than that for the apex, unlike the number of twists per unit length. This is to be expected as the fibres from the flanks have a greater mean length than the apical fibres, while the number of convolutions per mm. is the same for both the regions.

This variation in the total number of convolutions without a variation in their linear arrangement for nearly 50 per cent of the fibres, appears to support the view of Clegg and Harland [1924] that 'the form of the curve (of distribution of convolutions) is predetermined by environmental conditions prevailing during the period of growth in length of the hair'.

TABLE XXVI

Number of Convolutions per mm. and per fibre: All regions of the seed: Nandyal 14

Region	Convolutions per mm.	Percentage of fibres in each region: by weight	Percentage of fibres in each region: by number	Convolutions per fibre
Base	3·40	30	30·0	71·3
Apex	1·93	16	17·3	36·3
Right flank	2·00	23	20·7	44·3
Left flank	1·99	24	22·7	45·3
Combed fibres	2·68	7	9·3	50·9

In Table XXVI the average number of convolutions per mm. and per fibre are given for the different regions along with the percentage of fibres in the respective regions, both by weight and by number. From this the straight mean, and the weighted mean both by weight, and by number, are calculated and given below. For comparison the mean value for the bulk sample taken from the *Technological Reports* [Ahmad, 1931] is also given.

—	Technological Reports Bulk mean	Straight Mean	Weighted mean by number	Weighted mean by weight
Convolutions per mm. . . .	2·70	2·40	2·45	2·47
Convolutions per fibre . . .	62·5	49·6	51·9	51·9

It is seen from these figures that the mean value given in Technological Reports is higher than the other means in both cases. The differences among the three calculated means, are however inappreciable, except for the convolutions per fibre for which the straight mean is slightly smaller than the weighted mean.

The number of convolutions per mm. as given in *Technological Reports*, viz. 2·70 lies approximately midway between the means for the apical and the basal fibres, 1·93 and 3·40 respectively, and agrees with the mean for the combed fibres, 2·68. The average number of convolutions per fibre 62·5 given in *Technological Reports* is between the mean for the basal and the combed fibres and higher than for the other three regions.

Frequency polygons for the distribution of convolutions : All regions of the seed. The frequency polygons for the distribution of convolutions per mm. given in Table XXII are drawn in Fig. 6.

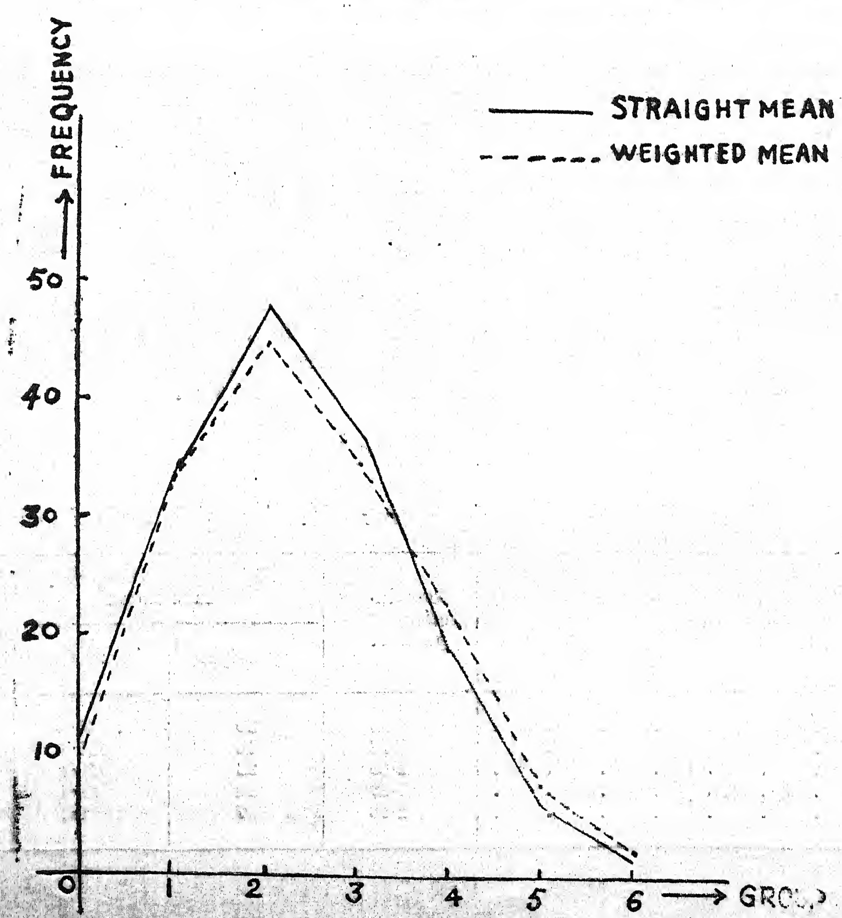

FIG. 6A. Frequency polygons : Convolution per mm. : All regions of the seed, Nandyal 14

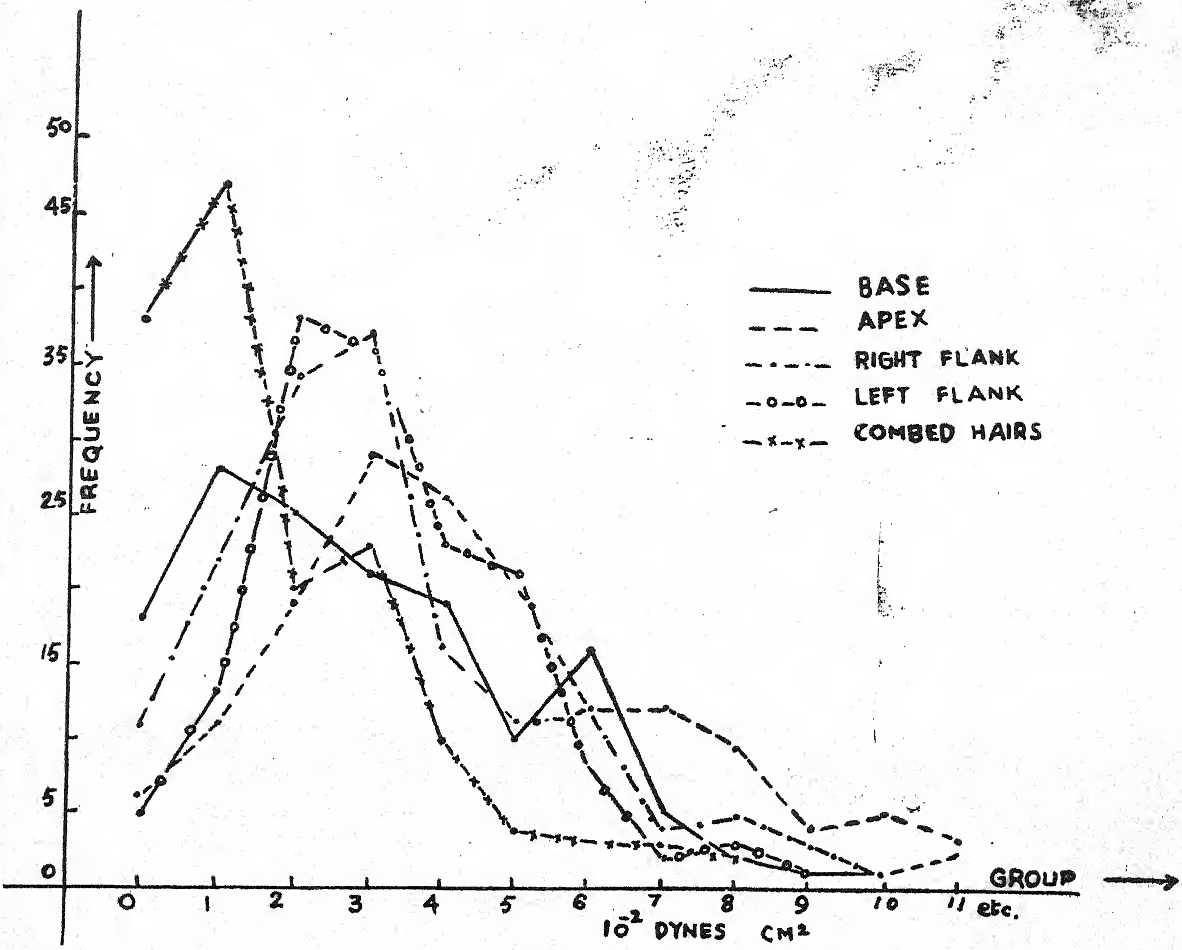

FIG. 6B. Frequency polygons: Convolutions per mm.: All regions of the seed, Nandyal 14

It is observed therefrom that all the polygons have nearly the same form and unlike those for rigidity are nearly normal. Except for the base and the apex, the curves for other regions nearly overlap. Koshal and Turner [1930] have shown that the general shape of the curve of convolutions is very nearly normal. From the present results it is found that the distribution in each individual region—fibres from which ultimately constitute the bulk sample—is similarly normal. Thus when a number of samples each with a normal distribution are mixed to yield the bulk the resulting distribution has also been normal.

This similarity in the form of distribution of convolutions among fibres from different regions even including the combed fibres which are probably undeveloped fibres indicates that the view of Clegg and Harland [1924] mentioned earlier that the form of distribution is predetermined by environment during the growth is true not only for the distribution in single fibres but also among a group of fibres, even though the convolutions are actually manifested after the fibre desiccates and collapses.

Superposed on these curves, are given those obtained by combining them on the basis of (1) straight mean, and (2) weighted mean (by weight), to thus represent the pattern of a bulk sample. These curves are almost identical and similar to the others being approximately normal.

Probable causes of regional differences in fibre properties

This investigation has shown that as much variation in the properties of the fibres on any one region of the seed can be expected as there are in a bulk sample and that there are considerable differences in the average fibre properties from region to region of the seed. While these tests do not claim to elucidate fully the causes of such variations a few general remarks may be offered.

(1) The nutritive system in the seed as envisaged by Balls [1915] is such that 'the vascular tissue enters the seed by its stalk, runs along the side and then breaks up at the wide butt of the seed into short distributing branches', thus fostering a better growth at the base at the expense of the apical region. The space for deposit of nutrient matter in the matrix is larger at the base than at the funicle or its approaches. Even a shortage in the supply store will naturally affect the last portion to which the food is supplied, viz. the funicular end as has also been alluded to by Balls [1915].

(2) A likely result of the first cause is the belated commencement of growth of lint at the apex as compared with the base, as stated by Matthews [1924] and Bowman [1908]. In addition, if lint length development is arrested after about the 25th day of flowering, apical fibres would be shorter than the basal ones, assuming a uniform rate of lint extension.

(3) The arrangement of the ovules in the ovary is such that they are crowded at the point of attachment, while large space is allowed at the farther end of the maturing ovules in the enclosing space provided by the base of the pistil or stigma. The adherence of the funicle to the placenta and the hard stalk of the stigma affects the growth of fibres at this end by constant pressure against the cells of the palisade layer.

The primary consequence of the above causes is the shortening of lint length at the apex as compared with the base. The changes in other properties are a result of this and the continuation of the growth processes after cessation of lint length development on or about the 25th day.

The shorter lint at the apex admits the same nutrient matter (as the flow becomes more and more uniform) to be deposited in a shorter length in the apical fibres which thus have a greater wall thickness as inferred earlier. The comparative scarcity of fibres in this part lessens the competition for food supply and aids thickening of the cell wall.

This thicker wall naturally prevents the convolutions from showing up, due to enormous resistive forces, as stated by Balls [1915] and Bowman [1908]. The stout wall endows the fibre with a high rigidity, as shown by the examination of fibres with abnormally high rigidity by Peirce [1923]. The slight tendency for greater ribbon width among the apical fibres may be due to the thicker wall as stated by Balls [1928].

The second type of variation noted above, viz. differences in the properties of the fibres on any one region of the seed suggesting a common genetical basis are most probably due to the differential nutrition supplied to the elementary cells during their growth and decay on the outer epidermis of the seed and their consequent reaction to different environmental conditions. In so far as the history of the fibres on any one part of the seed surface is concerned, the internal and external conditions of growth would be nearly the same, only if there is simultaneity in the birth of lint cells. Balls [1915] and Barritt [1932] hold the view that the differentiation of epidermal cells into lint hairs is primarily a single day phenomenon, while Turner [1929], Gulati, [1930], and others are of the opinion that it is a phenomenon spread over a number of days. The general variation observed in these tests appears to favour the latter view. As a consequence of a time lag in the birth and growth of neighbouring fibres the reactions of the growing lint hairs to varying conditions of temperature, humidity, sunshine and nutrient supply would result in the endowment of different properties to the neighbouring fibres.

These results also suggest a partial answer to a question raised by Turner [1929] about the rate of nutrient available to different regions of the seed during the lengthening and thickening stages of the fibres. The stunting of lint length has been made up by a thick wall in the apical fibres which suggests that the flow of nutrient, perhaps deficient in the early stages in this region, has tended to become more uniform during the later stages. The ratio between the flow of nutrient in the lengthening and the thickening stages seems smaller for the apical than for the basal fibres.

Summary and conclusion

While the differences in the fibre properties from region to region on the surface of the cotton seed have been investigated as regards (1) length, (2) weight, and (3) strength, by Koshal and Ahmad, the present tests deal with three more properties (1) rigidity, (2) ribbon width and (3) convolutions.

The materials are the same standard Indian cottons as were used in the previous investigation, viz. Nandyal 14, P. A. 4F., C. A. 9 (1928-29), C. A. 9 (1929-30), Gadag I (1928-29), Gadag I (1927-28), Verum 262 (Nagpur), and 1027 A. L. F., the slivers having been conjointly prepared by us. For all the eight samples fibres from the base and the apex were tested.

In the case of Nandyal 14 only, fibres from the other regions, viz. right flank and left flank and the combed fibres were also tested.

The experimental methods used are the same as those in vogue at the Technological Laboratory of the Indian Central Cotton Committee, Bombay.

From the analysis of the results of this investigation the following conclusions have been drawn :

(1) The fibres on the apical region of the seed possess higher fibre rigidity than those on the basal region, the difference between the mean values for the two regions varying from cotton to cotton and ranging between 39·0 per cent for C. A. 9 (1929-30) and 183·4 per cent for Gadag I (1927-28).

The combed fibres have the lowest rigidity and the apical fibres the maximum, the difference between them being 131·4 per cent.

The frequency distribution of fibre rigidity is asymmetrical not only for the base and the apex but also for the other regions as well. But while it is skew for the apical fibres, a J-shape tendency is observed for the basal fibres as also for a bulk sample.

The rigidity modulus for the material of the fibre remains practically the same for the basal and the apical regions though differing from cotton to cotton.

(2) The fibres in the apical region have practically the same ribbon width as those in the basal region for P. A. 4F, C. A. 9 and Verum 262, while for Nandyal 14, Gadag I and 1027 A. L. F. the apical fibres are significantly broader, the difference ranging from 9·0 per cent to 12·5 per cent from cotton to cotton.

The combed fibres have the maximum ribbon width with the apical, the right and the left flanks, and the basal fibres following in the given order. The maximum difference, which is between the basal and the combed fibres, is 17·6 per cent and it is significant, while the minimum difference between the two flanks is 1·1 per cent and not significant, the differences between all the other regions, however, being significant.

The frequency distribution of ribbon width is practically normal not only for the bulk but for each region also, unlike that of fibre rigidity for which the distributions in the different regions are dissimilar.

(3) The difference in the number of convolutions per mm. between fibres from the apical and the basal regions varies from 14·1 per cent for Gadag I (1928-29) to 43·3 per cent for Nandyal 14, and is statistically significant in each case. With the exception of P. A. 4F., the convolutions in the apical fibres are more widely spaced than in the basal fibres. In P. A. 4F., however, the convolutions are more crowded in the apical fibres. Generally the basal fibres have 25-30 per cent greater number of convolutions per fibre.

Judging from the ratio of ribbon width to convolutions as shown by Clegg, and the values of the product, length $\times \sqrt{\text{hair rigidity}}$ as shown by Peirce, it is inferred that the apical fibres generally have a greater wall thickness.

The basal fibres have the highest number of convolutions both per fibre and per unit length. While the number of convolutions *per mm.* or their linear density is lowest in the fibres from the flanks and the apex, the total number of convolutions *per fibre* is lowest in the apical fibres, those from the flanks and the combed fibres coming next in order.

The form of distribution of convolutions hardly differs either from cotton to cotton or from region to region on the seed surface, being normal for the bulk sample as well as for the fibres from the different regions of the seed.

These variations in the fibre properties, not only within a given region on the seed surface but also as between regions, are attributed to the time lag in the differentiation of neighbouring epidermal cells into lint hairs and the belated commencement of lint growth at the funicular end with a comparatively simultaneous cessation of lint length development, these again being the result of a relatively copious supply of nutrient matter at the base of the seed, particularly in the initial stages.

ACKNOWLEDGMENTS

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APPENDIX

Fibre rigidity

The fibre rigidity is calculated from the usual formula for a torsion pendulum $n = \frac{8 \pi I l}{T^2 a^4}$ where n=coefficient of rigidity, I=moment of inertia of suspended rod, l=length of fibre, T=periodic time and a=radius of the fibre, assuming the fibre to be a cylinder. Hence $\pi \; a^2$=A=area of cross section, $n = \frac{8 \Pi^3 I l}{T^2 A^2}$. Assuming that even though fibres differ in shape of cross section, the sectional area is less likely to vary from fibre to fibre and so taking A nearly constant, $n = \frac{8 \Pi^3 I l}{T^2}$ is the coefficient calculated and taken to represent fibre rigidity.

But as already noticed by Auerbusch [1923] a cotton fibre is ribbon-like and not cylindrical; further it is not a uniform cylinder but a twisted ribbon and, therefore, the above formula would not strictly be applicable.

Even as a comparative measure of the resistance offered by fibres to a torsional force, it is defective in as much as the assumptions underlying the formula may not be equally valid in the case of all fibres. This may be illustrated by analysing the effect of convolutions on hair rigidity.

If the convolutions are all in one direction then the initial torque applied through the inertia rod would further twist the fibre if the convolutions are in the same direction as the twist, or untwist the fibre if in the opposite direction. The effect becomes more complicated if, as they usually are, the directions of the convolutions themselves are often reversed. The torsion couple would meet with resistance by these twists before the torque would reach the top support. And this resistance would increase or decrease with the number of convolutions, decreasing or increasing respectively the periodic time. Apart from degree of wall thickness convolutions alone would thus influence the hair rigidity.

This analysis finds justification in the observed effect of humidity on hair rigidity, which can at least partly be explained by the change in the number of convolutions. A rise in humidity decreases convolutions [Denham, 1923] increasing the periodic time (of the torsion pendulum) thus decreasing the fibre rigidity, as found by Peirce [1924].

The twisting couple may not thus be able to exert its influence along the entire free length of the suspended fibre whereby taking the length as l would be inaccurate. If the convolutions are in different directions the inaccuracy increases.

A close examination of the fibre convolutions and of the rotation of the fibre at different points along its length from the free to the fixed end, when the fibre is under torsional stress might yield useful information.

The determination of fibre rigidity at different parts along the length of a fibre, instead of treating a whole fibre as a unit, would perhaps be more in consonance with the spinning processes which do not necessarily twist the entire length of a fibre at the same instant. Testing such short lengths would also minimise the effect of convolution on the hair rigidity formula.

Furthermore, even small variations in fibre diameter as it occurs in the fourth power in the formula would seriously affect hair rigidity.

Another point that was noticed during the present tests was the kinked appearance of some of the fibres suspended by the inertia rod ; obviously the weight of the rod was insufficient to stretch the fibre taut. And the formula would not be strictly applicable to such a system which may be linkened unto a degenerated open spiral.

The structure of the fibre as one made up of a number of concentric longitudinal tubes with intervening space, each tube having a fibrillar structure according to Balls [1928] makes the fibre non-homogeneous and the application of the formula would not be correct as any abnormality in the outer layers would seriously affect the torsion as it is in these layers that the strain is greatest as pointed out by Poynting and Thomson [1913]. The relative number of growth rings and their inter-ring distances might also affect rigidity.

Two modifications of the formula may now be considered : Since in a bulk sample the majority of the fibres would be more ribbon shaped than cylindrical, disregarding the effect of convolutions, we may use De St. Venant's [Poynting and Thomson,] formula for the torsional oscillations of a thin strip :

If c is the couple required to produce a rate of twist φ, then $c = n\varphi\pi \dfrac{a^3 b^3}{a^2+b^2}$. If b is small compared with a, $c=n\varphi\pi a b^3$ ($2a$ and $2b$ are the major and minor axes of the elliptical sections of the strip, n=coefficient of rigidity).

For the cotton fibres, b may be regarded as relatively constant as compared with a ; and a may be taken as half the mean measured width. Hence, $c= I\ddot{\theta} = n\varphi\pi a b^3$

If θ = total twist $= \pi a b^3 n\, \theta/l$.

And b being constant, $T \propto 2\pi\sqrt{\dfrac{I l}{\pi n a}}$

When T is periodic time $\therefore\ T^2 \propto \dfrac{4\pi I l}{n a}$

Putting $n = n_1$ $n_1 \propto \dfrac{4\pi I l}{T^2 a}$

$$\propto \frac{8\pi^3 I l}{T^2} \cdot \frac{1}{a}$$

Thus the value of hair rigidity obtained in these tests, divided by half the width of the fibre, may be a better index of fibre rigidity.

TABLE I.

Fibre rigidity values

Cotton	$\eta = \frac{8\pi^3 Il}{T^2}$ dynes cm^2 10^{-2}			$\eta_1 = 2\eta/\alpha$ dynes cm 10^{-3}			$\eta_2 = \eta/\omega_1^2$ dynes cm^{-4} gm^2 10^{10}		
	B	A	$\frac{A-B}{B}\times 100$	B	A	$\frac{A-B}{B}\times 100$	B	A	$\frac{A-B}{B}\times 100$
Nandyal 14	3·11	4·42	42·2	3·83	4·83	26·1	0·81	0·83	2·4
P. A. 4F.	1·97	5·06	156·8	1·95	4·93	152·8	0·63	0·59	—6·4
C. A. 9 (1928-29)	3·26	4·55	39·6	4·14	5·97	44·3	1·14	1·13	—0·9
C. A. 9 (1929-30)	2·82	3·89	38·0	3·81	5·13	34·7	0·98	1·00	2·1
Gadag I (1928-29)	2·00	4·77	138·5	2·89	6·20	113·6	0·91	0·99	8·8
Gadag I (1927-28)	1·99	5·64	183·4	2·92	7·39	153·3	1·03	1·15	11·6
Verum 262	4·17	8·77	110·3	5·16	11·12	115·2	0·98	1·38	40·7
1027 A. L. F.	3·00	6·66	122·0	3·34	6·84	104·8	1·16	0·73	—37·1

B = Base ; A = Apex.

The above Table gives the values of n and n_1 calculated according to the above formula. It is seen that the modified measure of fibre rigidity does not show any appreciable improvement over the usual one.

A second modification may be considered. Since $\frac{8\pi I l}{T^2\alpha^4} = \frac{8\pi^3 I l}{T^2(\pi\alpha^2)^2} = \frac{8\pi^3 I l}{T^2 A^2}$ (the symbols having the usual significance) $A \times l$ gives the volume of the fibre and $A\iota\sigma$, where σ = density of the material of the fibre, gives the weight of the fibre, assuming σ to be constant from fibre to fibre or from cotton to cotton, we have

$$\eta^1{}_2 = \frac{8\pi^3 I l}{T^2 A^2} = \eta/A^2$$

If $A\sigma$ = weight of a fibre = ω

$$\eta^1{}_2 \text{ Then, } = \frac{\eta.\ l^2\rho^2}{\omega^{12}}$$

In practice, the fibre weight and fibre rigidity are determined on different sets of fibres and the mean lengths of the fibres in each case are not generally identical. Hence if W_1 = fibre weight per unit length then $\omega = \omega_1 \iota$ Omitting the costant ρ, $\eta_2 = \frac{\eta}{\omega^{12}}$ may be taken to represent the comparative rigidity coefficient of the fibre for each cotton. In Table I of the Appendix, taking the values of η from the present tests and ω_1 from the results of Koshal and Ahmad [1932], the calculated values of η_2 and their regional differences are given. The range of these differences hardly exceeds 40 per cent. The cottons can be grouped into two classes (1) Verum 262 and 1027 A.L.F. for which the regional differences are large and (2) the rest for which the differences are small. It is to be noted that unlike η or η_1, the basal fibres give a higher value of η_2 in a few cases. For different seasons for a given cotton the relative regional difference is not appreciably altered.

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EFFECT OF COMPOSITION ON MOISTURE ABSORPTION PROPERTIES OF JAGGERY

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ONE of the important characters that enhance the market value of jaggery is its keeping quality; for the purpose of this paper, this has been considered as equivalent to the ability of the jaggery to resist absorption of moisture on exposure to humid air as the micro-organisms causing the actual deterioration can function only under favourable moisture conditions. In South India, particularly in places of heavy rainfall like Malabar and districts on the west coast, greater value is attached by the buyer to this character than even to its colour. The jaggery trader in evaluating his material is usually guided by its apparent hardness as this has generally a high correlation with keeping quality. But a surer method would be to measure its hygroscopic power on exposure to artificial atmospheres of definite relative humidities during a given period of time.

For the purpose of laboratory studies, atmospheres of any required relative humidity can be produced and maintained by keeping sulphuric acid of known density in closed desiccators [1921]. In all the experiments described in this paper, atmospheres of various relative humidities were obtained by this method only.

It is generally accepted that keeping quality of jaggery is intimately associated with its chemical composition: there however appears to be a difference of opinion as regards the nature of the particular constituent or constituents that control this important character. Rao and Ganapathy Iyer [1923] mainly from a comparison of the analytical results of a large number of jaggery samples with reference to their moisture-absorbing capacities, came to the conclusion that reducing sugars and chlorides exercised a dominating influence. Norris, Viswanath and Nair (1922) attributed the softening of cocoanut jaggeries to the excessive amounts of calcium chloride present therein. Varahalu [1935] has however concluded that organic non-sugars play a much more important role on the keeping quality of jaggery than any other of its ingredients. In view of the different conclusions arrived at by the previous workers and in view of the important nature of the problem, it was thought worthwhile to reopen investigations on this question in greater detail.

Experimental procedure

Laboratory experiments were conducted on the following lines:

(1) Glucose, levulose, gums, separated from canejaggery, and chlorides and sulphates of sodium, potassium and calcium were added individually to different portions of pure white sugar solution and these were converted into solid products by concentrating them over direct flame in the laboratory under as uniform conditions as possible. These jaggeries were analyzed and their moisture-absorbing capacities compared at definite relative humidities by keeping them in desiccators containing sulphuric acid of appropriate density and noting the change in weight.

(2) The reducing sugar content of sugar solution and cane juice was altered by changing the reaction before concentration and the jaggeries obtained by concentrating them were analyzed and their keeping qualities examined.

(3) Sugarcane and cocoanut jaggeries were extracted with ethyl alcohol or treated with other organic reagents and the treated materials were analyzed and compared for their keeping qualities.

Determination of Moisture Absorption by Jaggery at a Particular Relative Humidity

The sample of jaggery was well ground in a porcelain mortar and 5 gm. of the ground material were uniformly spread in a shallow, flat-bottomed weighing bottle 6 cm. in diameter and 3½ cm. deep.

Samples belonging to a particular experiment were placed in open weighing bottles of the same size and were all kept in a single desiccator containing dilute sulphuric acid of the requisite density at the laboratory temperature. The weighing bottles were closed with their corresponding lids just before weighing and the weights were noted daily for a period of about three weeks for each experiment. The position of the weighing bottles within the desiccator were changed from day to day so that each sample occupied various places in the desiccator before the conclusion of a particular experiment.

The original moisture in the samples taken for moisture-absorption studies was determined by weighing out separate portions of the above at the same time, and drying them to constant weight at the temperature of the steam oven after mixing them with well-cleaned sand. The dry matter was then calculated. To the amount of moisture thus found, was added the moisture absorbed at the conclusion of the experimental period and the total amount was expressed as a percentage of the dry matter in the sample.

Each experiment described in the paper envisaged the study of a particular question and therefore consisted of a control in addition to the different treatments. As all the samples relating to a particular experiment were placed within one and the same desiccator kept at the laboratory temperature, the small variations in temperature met with in the laboratory during the course of the day and from day to day may be presumed, without much error, to affect equally the moisture absorption rates of the samples of the different treatments relating to the particular experiment. The conclusions drawn will not therefore be vitiated by this circumstance of temperature fluctuations.

For the same reason, changes in the percentages of relative humidities at which moisture absorptions were determined for different experiments will not affect the nature of the conclusions drawn for any particular experiment.

Effect of dextrose and levulose on the keeping quality

Increasing amounts of laboratory samples of dextrose and levulose were added to bazaar sugar solution and these were concentrated in the laboratory to consistency suitable for conversion into a solid product. The final products so obtained were analyzed and their moisture-absorbing capacities were compared at 75 per cent relative humidity.

TABLE I

The effect of the addition of dextrose and levulose on the keeping quality

Particulars	Purity coefficient	Percentage of reducing sugar on dry matter	Percentage of moisture on dry matter under 75 per cent relative humidity and after a period of 10 days
Bazaar sugar 75 gm. + 300 c.c. of water boiled down to jaggery	99·0	0·50	0·79
Bazaar sugar 75 gm. + 1·5 gm. each of dextrose and levulose in 300 c.c. of water boiled to jaggery as in (1)	93·8	6·23	4·57
Bazaar sugar 75 gm.+3·0 gm. each of dextrose and levulose in 300 c.c. of water treated as before	88·3	10·5	8·15

The effect of varying the amounts of reducing sugar only in the jaggery on its keeping quality was then studied (1) with white sugar solution by changing its reaction by the addition of small amount of acid or alkali, and (2) with cane juice by boiling it down to jaggery before and after the addition of lime. The results are given below.

TABLE II

Effect of different amounts of reducing sugars on the keeping quality (starting with white sugar solution)

Particulars of treatment (1)	Purity co-efficient (2)	Reducing sugar (3)	Percentage of moisture on dry matter after a period of 3 weeks	
			60 per cent relative humidity (4)	80 per cent relative humidity (5)
75 gm. of sugar + 300 c.c. of water, boiled to jaggery consistency	97·2	0·50	1·51	2·36
75 gm. of sugar + 300 c.c. of water + 1 drop of strong acetic acid, boiled as above	95·5	2·30	1·50	4·86
75 gm. of sugar + 300 c.c. of water + 3 drops of strong acetic acid, boiled as usual	89·6	7·50	3·22	12·57
75 gm. sugar + 300 c.c. of water + 3 drops of 10 per cent sodium hydroxide	98·7	Traces	0·83	1·41

TABLE III

The effect of reducing sugar on the keeping quality (starting with cane juice)

Particulars	Percentage of reducing sugar	Percentage of moisture on dry matter during a period of 3 weeks under 80 per cent relative humidity
Test. I		
750 c.c. of juice, boiled down to jaggery	14·08	15·32
750 c.c. of juice, limed to litmus neutrality before concentration	8·10	11·10
750 c.c. of juice overlimed before concentration	5·09	9·83
Test. II		
750 c.c. of juice, boiled down to jaggery	19·35	19·25
750 c.c. of juice limed to litmus neutrality before concentration	13·09	14·82
750 c.c. of juice overlimed before concentration	10·86	13·24

The above data furnish strong evidence to the conclusion that one of the majorfactors that govern the keeping quality is the reducing sugar content.

Effect of salts

A series of experiments on similar lines to the above were carried out to determine the effect of various salts—particularly the chlorides and sulphates of sodium, potassium, and calcium on the keeping quality of jaggery.

TABLE IV

Effect of increasing amounts of sodium chloride

Particulars of treatment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter during a period of 3 weeks	
			75 per cent relative humidity	100 per cent relative humidity
Bazaar sugar 75 gm. + 300 c.c. of water, boiled and solidified	98·4	0·84	1·27	25·7
75 gm. sugar + 0·37 gm. of sodium chloride + 300 c.c. of water, boiled as before	97·6	1·23	4·50	35·4
75 gm. sugar + 0·75 gm. of sodium chloride + 300 c.c. of water boiled as before	97·3	1·38	7·45	41·7
75 gm. sugar + 1·5 gm. of sodium chloride + 300 c.c. of water, boiled as before	96·0	1·45	11·67	48·9

TABLE V

Effect of increasing amounts of potassium chloride

Particulars of treatment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter during a period of three weeks	
			60 per cent relative humidity	80 per cent relative humidity
75 gm. of sugar + 300 c.c. of water, boiled and solidified	98·8	0·59	*Nil*	*Nil*
75 gm. sugar + ·37 gm. of potassium chloride + 300 c.c. of water, boiled as before	98·8	0·69	1·25	5·35
75 gm. sugar + ·75 gm. of potassium chloride + 300 c.c. of water, boiled as before	98·6	..	1·34	7·89
75 gm. sugar + 1·5 gm. of potassium chloride + 300 c.c. of water, boiled as before	97·7	0·69	1·11	13·69

TABLE VI

Effect of increasing amounts of calcium chloride

Particulars of treatment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter	
			60 per cent relative humidity	80 per cent relative humidity
(a) 75 gm. sugar dissolved in 300 c.c. of water, boiled and solidified	98·2	0·42	*Nil*	2·19
(b) 75 gm. sugar and ·37 gm. of calcium chloride dissolved in 300 c.c. of water, boiled as before	96·5	1·97	0·89	5·30
(c) 75 gm. sugar and ·75 gm. of calcium chloride dissolved in 300 c.c. of water, boiled as before	95·6	1·94	0·80	6·77
(d) 75 gm. sugar and 1·5 gm. of calcium chloride dissolved in 300 c.c. of water, boiled as before	94·4	1·95	2·71	11·45

TABLE VII

Effect of sodium sulphate

Particulars of treatment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter	
			60 per cent relative humidity	80 per cent relative humidity
(a) 75 gm. of sugar + 300 c.c. water, boiled and solidified	99·7	0·55	0·98	2·12
(b) 75 gm. of sugar + ·37 gm. of sodium sulphate, boiled as before	99·1	0·37	0·95	3·24
(c) 75 gm. of sugar + ·75 gm. of sodium sulphate, boiled as before	..	0·41	0·79	4·77
(d) 75 gm. of sugar + 1·5 gm. of sodium sulphate, boiled as before	97·8	0·47	0·56	8·11

TABLE VIII

Effect of potassium sulphate

Particulars of treatment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter	
			60 per cent relative humidity	80 per cent relative humidity
(a) 75 gm. of sugar + 300 c.c. of water, boiled and solidified	97·8	..	*Nil*	0·32
(b) 75 gm. of sugar + 0·37 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before	97·2	..	*Nil*	1·14
(c) 75 gm. of sugar + 0·75 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before	97·3	..	*Nil*	1·20
(d) 75 gm. of sugar + 1·5 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before	95·5	..	*Nil*	1·32

TABLE IX

Effect of calcium sulphate

Particulars of treatment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter	
			60 per cent relative humidity	80 per cent relative humidity
(a) 75 gm. of sugar dissolved in 300 c.c. of water, boiled and solidified	99·7	0·47	0·25	1·12
(b) 75 gm. of sugar dissolved in 300 c.c. of water, + 0·37 gm. of calcium sulphate	99·1	0·57	0·53	1·61
(c) 75 gm. of sugar dissolved in 300 c.c. of water, + 0·75 gm. of calcium sulphate boiled as before	98·2	0·72	0·67	2·27
(d) 75 gm. of sugar + 300 c.c. water + 1·5 gm. calcium sulphate, boiled as before	97·5	0·74	0·87	2·11

Effects of the chlorides of sodium, potassium and calcium compared

The chlorides of each of these elements were added in quantities sufficient to supply 0·5 gm. of chlorine in each case.

TABLE X

Comparison of the effects of chlorides of sodium potassium and calcium

Particulars of the experiment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter	
			60 per cent relative humidity	80 per cent relative humidity
75 gm. of sugar dissolved in 300 c.c. of water, boiled and solidified	99·4	0·47	0·04	0·70
75 gm. of sugar + 0·82 gm. of sodium chloride dissolved in 300 c.c. of water, boiled and solidified	98·0	0·65	2·20	8·08
75 gm. of sugar + 1·05 gm. of potassium chloride dissolved in 300 c.c. of water, boiled as before	98·1	0·54	0·58	7·25
75 gm. of sugar + 0·82 gm. of calcium chloride dissolved in 300 c.c. of water, boiled as before	96·2	2·05	1·92	7·49

Effect of sulphates of sodium, potassium and calcium

The sulphates of the different metals were added to supply 0·5 gm. of SO_3 per 75 gm. of sugar.

TABLE XI

Effect of sulphates of sodium, potassium and calcium

Particulars of treatment	Purity co-efficient	Percentage of reducing sugar	Percentage of moisture on dry matter	
			60 per cent relative humidity	80 per cent relative humidity
75 gm. of sugar + 300 c.c. of water, boiled and solidified	99·1	0·45	0·41	1·06
75 gm. of sugar + 0·9 gm. of sodium sulphate dissolved in 300 c.c. of water, boiled as before	98·1	0·48	0·35	4·62
75 gm. of sugar + 1·1 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before	97·2	0·73	0·31	1·60
75 gm. of sugar + 0·9 gm. of calcium sulphate dissolved in 300 c.c. of water, boiled as before	97·9	0·67	0·45	1·27

It will be seen that each of the chloride samples has absorbed high amounts of moisture under 80 per cent relative humidity. As regards sulphates, the sulphates of potassium and calcium have caused the absorption of only a little more moisture than the control. Sodium sulphate sample on the other hand has absorbed fairly large amounts though the moisture absorbed is only slightly more than half of that for sodium chloride.

In the boiling trials conducted in the laboratory as above, perfect control of the experimental conditions could not be secured. For example the period of boiling in these tests varied by a few minutes (5 to 10 minutes) and the temperature at which the change was struck varied by a degree on either side. To determine how far these small variations would affect the accuracy of the observations noted above, further experiments were conducted, varying the duration of boiling only.

TABLE XII

The effect of small variations in the period of boiling and striking temperature on the composition and keeping quality of jaggeries, prepared from pure sugar solutions

Particulars of treatment	Period of boiling	Final striking temperature	Purity	Percentage of reducing sugar	Percentage of moisture on dry matter	
					60 per cent relative humidity	80 per cent relative humidity
	H. M.					
75 gm. of bazaar sugar + 300 c.c. of water, boiled and solidified	1—20	122°C.	99·4	0·38	0·61	1·32
Do.	1—35	123°C.	99·5	0·54	0·56	1·55
Do.	1—35	123°C.	99·5	0·54	0·69	1·41
Do.	1—39	121°C.	98·7	0·54	0·37	1·16
Do.	1—45	122°C.	99·1	0·79	0·38	1·14
Do.	4— 0	123°C.	97·6	1·43	0·86	2·69

It will be seen that the variations observed in the moisture contents of the above samples fall within rather narrow limits, showing thereby that the differences noted previously between samples under various treatments are real and not due to experimental error.

In the experiments quoted above, the line of attack has been to add directly to sugar solutions of the same strength known amounts of various salts, to prepare jaggeries out of them and to compare these different products as to their keeping qualities. Additional evidence was sought to be obtained on the question by adopting a different method of attack, viz. a study of the comparative behaviour of cane and cocoanut jaggeries.

Cane jaggeries ordinarily contain more glucose and less chlorides than cocoanut jaggeries and a study of the keeping qualities of these jaggeries revealed that in spite of their low glucose content the cocoanut jaggeries absorbed as much moisture as the cane jaggeries as shown below :

TABLE XIII

Comparison of the composition and keeping quality of cane and cocoanut jaggeries

	Particulars	Percentage of sucrose	Percentage of glucose	Purity co-efficient	Percentage of chlorine	Percentage of moisture on dry matter 75 per cent relative humidity
I	Cream jaggery : Cane—Poovan variety	81·34	7·90	86·86	0·525	10·57
I	Cream jaggery : Cocoanut	84·24	3·44	91·66	0·850	9·82
II	Poovan ordinary jaggery	..	15·63	..	0·415	14·80
II	Cream jaggery : Cocoanut	..	4·09	..	1·110	14·50

The above results show that the chlorides do play no less an important role than glucose in regard to its effect on keeping quality.

Effect of gums

The effect of the so-called gums of sugarcane products which include protein, gums and pectins were next investigated and this was studied in two ways. Firstly, a sample of ordinary cane jaggery was dissolved in water to give a concentration of roughly 50 per cent total solids and the gums were precipitated from this solution by means of 95 per cent alcohol. The gums were filtered off and the filtrate was boiled down into jaggery. The jaggery so prepared was analysed and its keeping quality compared with that of the original jaggery.

Secondly, the gums separated as above were washed thoroughly with 80 per cent alcohol, dried and mixed with bazaar white sugar. This was dissolved in water and boiled down into jaggery in the usual way. The composition and keeping quality of this product were compared with those of the product from white sugar. The results are presented below :

TABLE XIV

Effect of the 'gums' separated from jaggery on keeping quality

Particulars	Percentage of sucrose	Percentage of glucose	Percentage of gums	Percentage of chlorine	Percentage of moisture on dry matter 75 per cent relative humidity
Cane jaggery from Co 360	83·22	8·03	0·86	0·417	10·15
The above jaggery dissolved in an equal quantity of water, boiled again into jaggery	76·50	10·69	1·56	0·417	12·20
Gums removed by precipitation with 95 per cent alcohol, filtrate boiled down into jaggery	79·32	10·69	0·05	0·490	11·34
Bazaar sugar 75 gm. dissolved in 100 c.c. of water, made into jaggery	94·79	0·33	..	..	0·23
Sugar 75 gm. + 1·85 gm. of gums dissolved in 100 c.c. of water, boiled into jaggery	93·17	0·88	..	..	0·97

The results strongly indicate that the adverse effect of gums on the keeping quality of jaggery is comparatively small while that of glucose and chlorides is very pronounced indeed.

The study of the problem under question was continued by carrying out investigations involving a different line of attack.

Jaggeries from both cane and cocoanut were subjected to various treatments such as clarification with activated carbon and kieselgurh, and extraction with various organic solvents resulting in the removal of one or more of their ingredients. The jaggeries so treated were analyzed and their moisture absorbing capacities estimated in the usual way.

In the following experiment, a sample of cane jaggery was successively extracted at room temperature with (a) 95 per cent ethyl alcohol saturated with sodium chloride, (b) with 95 per cent ethyl alcohol, and (c) again with 95 per cent ethyl alcohol. The original jaggery and the different products obtained after extraction were analyzed for various constituents and their moisture absorbing capacities at 75 per cent relative humidity were also determined. The data are given below :

TABLE XV

Composition and moisture absorbing power of jaggery before and after extraction with 95 per cent ethyl alcohol saturated with sodium chloride and with pure 95 per cent alcohol

Heads of analysis and other particulars	Original jaggery	After extraction with 95 per cent alcohol saturated with NaCl (a)	(a) Extracted with 95 per cent alcohol (b)	(b) Extracted with 95 per cent alcohol (c)
		Percentage on dry basis		
Sucrose	82·11	82·64	88·08	..
Glucose	11·60	5·50	1·38	..
Chlorine	0·553	0·543	0·366	0·086
Nitrogen	0·039	0·043	0·040	0·042
Gums	0·755	0·698	0·700	..
Moisture absorbed under 75 per cent relative humidity calculated on dry matter	16·27	11·74	6·42	4·62
Percentage decrease in moisture absorbed . . .	..	27·84	60·53	71·60

It will be seen that as a result of extraction with 95 per cent ethyl alcohol saturated with sodium chloride, the jaggery lost about 50 per cent of glucose but very little of chlorine, nitrogen and gums and there is a noticeable reduction in the percentage of moisture absorbed. This indicates that the improvement in keeping quality exhibited by the extracted material is possibly due to the partial removal of glucose. When the above product is again subjected to repeated extraction with pure 95 per cent ethyl alcohol, a further marked loss in the glucose percentage and an appreciable reduction in the chlorine content are noticed; but no change in the nitrogen or gums percentages is observed. The improvement in the keeping quality has been very marked, thus demonstrating the adverse effect of glucose and chlorine on the keeping quality of jaggery.

The effect of the partial removal of nitrogenous substances and gums from jaggery without change in the glucose and chlorine percentages was studied as follows:

Cane and palmyra jaggeries were dissolved in water, clarified with activated carbon and reboiled into jaggery. In another experiment, the reconverted jaggery was extracted with 95 per cent ethyl alcohol. These different products were analyzed and their keeping qualities compared in the usual manner. The data are presented below:

TABLE XVI

Analysis and keeping quality of a sample of cane jaggery before and after treatment with activated carbon

Heads of analysis	Original jaggery (a)	(a) After clarification with activated carbon (b)	(a) Dissolved in water and reboiled into jaggery (c)
	Percentage on dry basis		
Sucrose	88·1	89·1	84·9
Glucose	7·71	8·09	9·35
Ash	2·045	2·380	2·065
Chlorine	0·251	0·391	0·259
Gums	0·367	0·061	0·321
Nitrogen	0·059	0·038	0·061
Moisture absorbed from an atmosphere of 75 per cent relative humidity	9·80	11·15	10·95

In spite of the great reduction in the gums fraction and a perceptible reduction in the nitrogen percentage, sample (b) has not shown any improvement in keeping quality; on the other hand, a deterioration in quality is noticed possibly due to its higher chlorine content.

TABLE XVII

Palmyra jaggery before and after treatment

Heads of analysis	Palmyra jaggery (a)	(a) Treated with activated carbon and kieselgurh (b)	(b) Extracted with 95 per cent alcohol (c)	(a) Extracted with 95 per cent alcohol (d)
		Percentage on dry basis		
Sucrose	88·12	90·88	93·83	88·82
Glucose	3·04	3·40	1·43	1·72
Ash	5·146	3·211	2·117	4·641
Chlorine	0·748	0·741	0·417	0·583
Gums	0·533	0·205	0·182	0·487
Nitrogen	0·173	0·133	0·100	0·159
Moisture absorbed from an atmosphere of 75 per cent relative humidity period from 22-11-44 to 5-12-44	12·36	11·69	7·03	8·18

The above results furnish additional evidence to show that it is the glucose and chlorine fraction and not the gums and nitrogenous fraction in jaggery that harms its keeping quality. Comparing (a) and (b), it will be seen that there is practically no change in the glucose and chlorine contents; but more than 60 per cent of the gums and about 25 per cent of the nitrogen have been removed; yet no improvement in keeping quality is visible. Again on comparing (a) and (d) one will notice a considerable reduction in the glucose and chlorine percentages and practically little change in the gums and nitrogenous fractions. The improvement in the keeping quality of (d) over that of (a) is marked. The inference appears to be obvious.

Discussion of results

The harmful influence of chlorides of sodium, potassium and calcium and the sulphate of sodium and that of reducing sugars has been demonstrated by straight experiments in which the above substances were individually added to pure sugar solutions, the solutions thus made were subsequently converted into jaggeries and the products finally obtained were compared for their moisture absorbing capacities with reference to their chemical composition. Confirmatory evidence in support of the above conclusion was obtained by experiments which involved the removal of particular constituent or constituents from jaggeries by treating the latter with suitable reagents including organic solvents and activated carbon and subsequent comparison of the treated product with the original jaggery for their keeping qualities. Thus extraction of a sample of jaggery in the cold with 95 per cent ethyl alcohol saturated with sodium chloride removed an appreciable portion of reducing sugars but practically little of the chloride, gums or nitrogenous fraction from the jaggery and as a result the extracted product revealed an appreciable improvement in keeping quality. Subsequent extraction of the treated production with 95 per cent ethyl alcohol effected a further reduction in the reducing sugar content and a considerable reduction in the chlorine content, but again very little of the gums and nitrogenous matter was removed. As expected a further improvement in the keeping quality was noticed.

On the other hand, treatment of the sample of jaggery with activated carbon leading to considerable reduction of the gums and nitrogenous substances but without any effect on the reducing sugars or chloride did not produce any improvement in the keeping quality of the jaggery.

A comparative study of the composition and keeping quality of typical samples of palmyra(cocoanut) jaggery and cane jaggery has supplied further evidence in support of the above conclusion. Palmyra or cocoanut jaggery is characterized ordinarily by low glucose and high chlorine contents, whereas cane jaggery possesses in general a higher glucose and a lower chlorine content. In spite of the low glucose percentage, cocoanut jaggery has been found to absorb moisture to as high a level as the sample of cane jaggery possibly due to its high chlorine content.

The above conclusion is however quite contradictory to the one arrived at by Varahalu, viz. that organic non-sugars exercise a very potent influence on the keeping quality of jaggery whereas glucose and chlorides play only a very minor role in this respect. It may be mentioned in this connection that his experiments were confined to mere observations of the setting quality of sugar solutions as influenced by the addition of varying amounts of glucose and chlorides to the former. He did not carry the study further to compare the moisture absorbing capacities of the different products obtained as a result of the various treatments.

It is pertinent and of interest to record here the observations made regarding the behaviour of cane juices clarified with activated carbon but unlimed and that of juices limed but not treated with activated carbon. It is well known that cane juices treated with activated carbon boil smoothly without frothing up to the striking point, presumably due to the removal of non-sugar colloids as a result of the activated carbon treatment. Some of these juices however do not set readily at the striking point and the jaggeries obtained are soft. On the other hand cane juices clarified with lime alone give rise to considerable frothing and the boiling is not smooth. They however set readily when concentrated to the proper consistency and the jaggeries are hard. These observations suggest that the removal of non-sugar organic colloids from the juice, as in the case of carbon-treatment, do not seem to help in the setting of the final thick syrup and in the production of a hard jaggery,

and contrariwise that the non-removal of the organic colloids, as in the treatment of the juice with lime only, does not appear to prevent the final syrup from setting readily and giving rise to hard jaggery. When it is remembered that activated carbon treatment removes from the juice a considerable portion of the colloids but little of the glucose and that mere lime treatment greatly minimises inversion of sucrose into glucose but effects little change in the colloidal content of the juice, the conclusion appears to be inevitable that it is mainly the glucose and the glucose decomposition products that interfere with the setting of the final syrup and the quality of the resultant jaggery.

Summary

It is generally known that keeping quality of jaggery is intimately associated with its chemical composition; but the chief constituent or constituents which control this charater has been a matter of controversy.

Evidence has been furnished in this paper to prove that reducing sugars and chlorides play a very important role on the moisture-absorbing capacity of jaggery and that organic non-sugars including the so-called 'gums' and nitrogenous substances exert only a comparatively minor effect.

Experiments leading to the above conclusion included the following set of experiments:

(a) Jaggeries were prepared on a laboratory scale from white sugar solutions to which various amounts of the chlorides and sulphates of sodium, potassium and calcium, of dextrose and levulose and of the so-called 'gums' separated from cane jaggery had been added. The moisture-absorbing capacities of the above products showed that the chlorides among the salts studied and dextrose, levulose and the reducing sugars increase the moisture-absorbing capacity of the jaggery to a considerable extent.

The so-called 'gums' appeared to produce only a comparatively small effect.

(b) Jaggery samples were successively extracted with 95 per cent ethyl alcohol in the cold, resulting in considerable reduction of the reducing sugars and chlorine contents without however any appreciable effect on the 'gums' and nitrogenous fractions. These extracted products showed a marked improvement in keeping quality as a result of the treatment.

On the other hand jaggery solutions on clarification with activated carbon and kieselgurh lose a considerable proportion of the gums and a fair portion of the nitrogen, but very little of the reducing sugars or the chlorides. These clarified solutions on conversion into solid jaggery showed, however, no improvement in the keeping quality.

(c) A comparison of the composition and keeping qualities of typical cane and cocoanut jaggeries furnished additional evidence in support of the above conclusion.

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SOME OBSERVATIONS ON THE WATER RELATIONS OF SUGAR CANE PLANT IN NORTH BIHAR

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(With four text figures)

SUGAR-CANE is essentially a tropical plant. In Bihar the cane growing tract entirely lies in the sub-tropical region. This cane tract is sub-divided into two by the intervening river Ganges. The sub-tract north of Ganges, popularly known as North Bihar, is more intensively cultivated with cane than the region south of the river. Soil of North Bihar, is rich alluvium widely varying in texture from place to place. At places it is underlain with pockets of sand. During the monsoon season the downward movement of rain water is quick and in the process soil and sub-soil both become completely saturated with moisture. This happens because of the calcareous nature of the soil. The presence of lime reduces the cohesive force amongst the particles and in consequence not only the penetration is quick but also the field saturation capacity of the soil is high. The plant roots spread out in a wide circumference and show deep penetration both in the soil and the sub-soil. This enables the crops to subsist on the stored soil moisture during the non-rainy periods and realize the maximum benefit out of the precipitation received during the monsoon season. Thus it is the ease with which soil is able to deliver water to the imbibing surfaces of the plant roots that the cane crop is grown without artificial irrigation in North Bihar. The annual precipitation in this cane growing region is about 45 in. At the foot of the hills it is more abundant than in the region close to the Ganges. The major portion of the rainfall is received in the monsoon period. Cane crop occupies the land from 9-11 months and this period may broadly be divided into three seasons, namely, summer, monsoon and winter. In North-Bihar, because of the unirrigated nature of the crop, hot weather forms the critical stage in the growth cycle of the crop. Under such environmental conditions the relationship between available soil moisture and plant growth is not quite a simple one. Growth effected is not only determined by the distribution of rainfall but also depends upon the nature of the critical or stress periods, which precede, intervene or succeed this precipitation. The object of the present contribution is a preliminary attempt to elucidate the relation of the cane plant to soil moisture under such environmental conditions.

Historical

The first systematic attempt to determine soil-water-growth relationship was made by Briggs and Shantz [1912 and 1914]. Briefly their studies conclusively showed that the lowest limit of available soil moisture for uninterrupted growth of plants is the wilting coefficient of the soil. Soil moisture above this limit is readily available both for metabolic and transpiration processes of the plant. At or below wilting coefficient water in the soil is not readily available for transpiration purposes and plants enter their quescent state of wilting [Luthra and Raheja, 1933], when slow rate of water absorption continues to some extent till complete desiccation occurs, the plants during the drying stage simply acting as the medium for the transference of water from the soil to air. Briggs and Shantz [1912] observed from their experimental evidence that plants differed but slightly in their ability to deplete the moisture content of any given soil. Alway [1913] found that under normal conditions plants were able to reduce the moisture content of the soil to the hygroscopic coefficient. This, however, does not imply that plants can utilize for growth the small amount of water available between the limits of the wilting and the hygroscopic coefficients of the soil. On the contrary this portion of water has a very high value for the maintenance of life under conditions of extreme aridity. Briggs and Shantz [1916] also concluded from their studies that crop plants widely differed in their relative water requirements. Maximov [1929] confirming the above conclusion further stated that drought resistant plants do not necessarily have a low water requirement. Their drought resistance is due to a multiplicity of morphological and physiological characteristics. From extensive studies on water

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balance of drought resistant plants, wild and cultivated, he concluded that physiologically drought resistant plants are better capable of maintaining their water balance under conditions of drought stress than the less resistant ones and that they invariably transpire at a much faster rate under conditions of abundant water supply. His conclusions accord with the theoretical analysis given by Huber [1923] for the maintenance of water balance of plants. With this brief survey of the fundamental work on water relations of plants we proceed to describe the investigations.

INVESTIGATIONS AND METHODS

The undermentioned aspects of the problem of water balance were studied:

1. Water content and diurnal moisture deficit in cane leaves
2. Rate of water loss during the course of wilting
3. Relative rate of transpiration from varieties during the hot weather stage of the cane plant
4. Relative rate of transpiration from varieties during the maturition stage of the crop

The technique and the methods employed for the study of the investigations are briefly stated below.

Determination of water content and leaf moisture deficit

Five sugar cane varieties sharply contrasting in their physiological nature, especially in respect of their drought resistant capacities as evidenced by visual observations in the field, were selected for the above studies. These had veen grown in the same field for experimental work. Leaf samples were drawn at two-hourly intervals. For each of the samples of a given variety five standard (transverse mark) leaves from five of the stalks were removed and were immediately transferred to weighed bottles which were capped air tight. For each of the varities three such samples on every occasion were removed. All the fifteen sample bottles were removed to the laboratory where these were weighed. The leaf samples were dried at 95°C. in an electrically operated air oven to a constant weight. Leaf moisture in every case was calculated on original fresh weight of the sample. The sampling for the hot weather was done in the month of May on three clear days. Five such estimations in the months of July and August were made for the nonsoon period. For the cold weather again three similar estimations were recorded in November. With a view to elucidate the varietal differences in each of the seasons mean values for each of the varieties have been worked out to compare the seasonal effect on the leaf moisture variations amongst the various varieties.

Rate of water loss during the course of wilting

Ten varieties similarly differing in their physiological traits, including the five varieties taken for the above experiments, were studied to determine the rate of water loss during the course of wilting of cut shoots. Immediately after cutting each of the shoots was weighted in a glass jar, and transported to the laboratory close by, the actual time of weighing being noted in every case. The weight of the shoot was recorded up to the second place of decimal. The period between the first weighing in the field and the second in the laboratory has been termed the 'period of conditioning'. So long as the shoots were small and could be contained in a glass container they were carried to the laboratory as such. Later on, however, it was not possible to do so and the shoots were brought to the laboratory without the container. Because of this difference in treatment of the shoots the differences noticed during the 'period of conditioning' for the various seasons have not been compared. Subsequent weighings hereafter were taken regularly at half hour intervals. In all 8 to 10 weighings in each case were recorded. At the end of the period the dry weights of the shoots were determined. Therefrom, on dry weight basis, the rate of water loss for each of the intervals was calculated. These determinations were made during each of the three seasons and the results given in the test are the mean values of the three readings. The experiments were carried out in May for the hot weather, in July and August for the monsoon season and in November for the cold weather.

Relative rate of transpiration from varieties during hot and cold weathers

Uniformly grown plants of nine varieties, including the five taken for the previous studies, were subjected to experiment. The pots had a size one foot square in cross section and two feet in depth.

In mid-April earthenware jars of about 600-700 c.c. capacity, with open mouth of about one inch in diameter, were fixed for making up the loss in soil moisture due to transpiration. To do away with the surface evaporation soil surface of the pots was waxed. Prior to the sealing of the soil the soil moisture of the pots was brought to field saturation capacity of the soil. Daily weighings for determining the transpiration loss were recorded each day in the morning at about 8 A.M. The loss of water was made good in each case through the earthenware jars. Five plants of each variety were under experiment. Weighments were begun in early May and continued for five weeks. Height measurements of the mother shoots indicated that plants made small growth because of the intense atmospheric aridity prevailing then. At the close of five weeks' period dry matter of the actively transpiring foliage was separately determined from the rest of the plant and on the basis of foliage weight, transpiration ratios were worked out for every plant. The roots of plants were washed with the needed care over a fine wire gauze of 225 meshes to a square inch. After washing the roots they were cleaned of all extraneous matter and their dry weight was determined. From the dry weights of the foliage and the roots, foliage root ratios were worked out and the results have been interpreted in relation to transpiration ratios of varieties under experiment.

Similarly treated plants were employed for the study of the transpiration rates of varieties during the cold weather months. In order to determine the transpiration intensities of the varieties leaf areas of the varieties were determined at the beginning and at the close of the experiment. The transpiring area was determined by the procedure described by Khanna [1934]. Briefly stated it consisted of multiplying leaf length with the leaf breadth at the widest point and leaf area factor determined for most of these varieties, *i.e.* 0·7005. Since both surfaces of the leaf transpire, twice the area of leaves was taken as the transpiring area of the foliage. Dry matter of the foliage and roots was determined at the close of the experiment for the purpose already stated for the hot weather series.

Experimental results

Mean values of leaf moisture for the various varieties, on different dates, at different hours of the day, have been set down in Table I and graphed in Fig. 1a.

Table I

Per cent leaf moisture data obtained during hot weather

Time/Date	7.0 A.M.	9.0 A.M.	11.0 A.M.	1.0 P.M.	3.0 P.M.	5.0 P.M.
			Variety—Co213			
9/5	75·50	73·50	72·20	72·00	71·87	71·70
16/5	77·38	76·63	74·54	73·86	73·58	73·48
26/5	75·11	73·59	72·95	72·06	71·85	71·64
Mean	76·00	74·57	73·23	72·64	72·43	72·27
			Variety—Co313			
9/5	75·30	73·80	71·20	70·25	70·70	70·50
16/5	76·83	74·02	73·49	71·51	71·07	71·36
26/5	72·52	71·64	72·70	69·24	69·31	68·68
Mean	74·88	73·15	72·46	70·33	70·36	70·18
			Variety—Co210			
9/5	74·50	73·70	73·20	72·60	71·20	73·20
16/5	68·39	78·17	75·27	74·27	71·85	72·72
26/5	76·29	74·46	72·67	71·42	70·04	71·42
Mean	76·39	75·44	73·71	72·76	71·03	72·45

TABLE I—*contd.*

Per cent leaf moisture data obtained during hot weather—contd.

Time/Date	7.0 A.M.	9.0 A.M.	11.0 A.M.	1.0 P.M.	3.0 P.M.	5.0 P.M.
			Variety—Co285			
9/5	72·70	71·20	69·70	68·80	68·90	69·30
16/5	74·10	74·50	73·91	72·90	72·30	72·70
26/5	72·95	71·61	70·47	69·01	68·36	69·54
Mean	73·25	72·44	71·36	70·24	69·85	70·51
			Variety—Co331			
9/5	71·60	70·80	70·70	70·10	70·80	71·60
16/5	73·90	72·98	72·25	72·09	72·98	73·73
26/5	72·60	71·54	70·78	69·87	69·15	69·54
Mean	72·70	71·77	71·24	70·69	70·98	71·62

A perusal of the results indicates that as the day advanced leaves tended to exhibit saturation deficit. During the hot weather usually leaf moisture did not show a recovery till 3.0 P.M. In the case of Co213 and Co313 a further drop was observed at 5.0 P.M. while varieties Co210 and Co285 had higher water content at 5.0 P.M. than at the preceding hour. Variety Co331 began to make up its water deficit before 3.0 P.M. The mean maximum saturation deficit, on the original leaf water content, at 7.0 A.M., in the decreasing order in the varieties, was Co210, Co213, Co313, Co285 and Co331 (Fig. 1a). The analysis of the data is given in Table II.

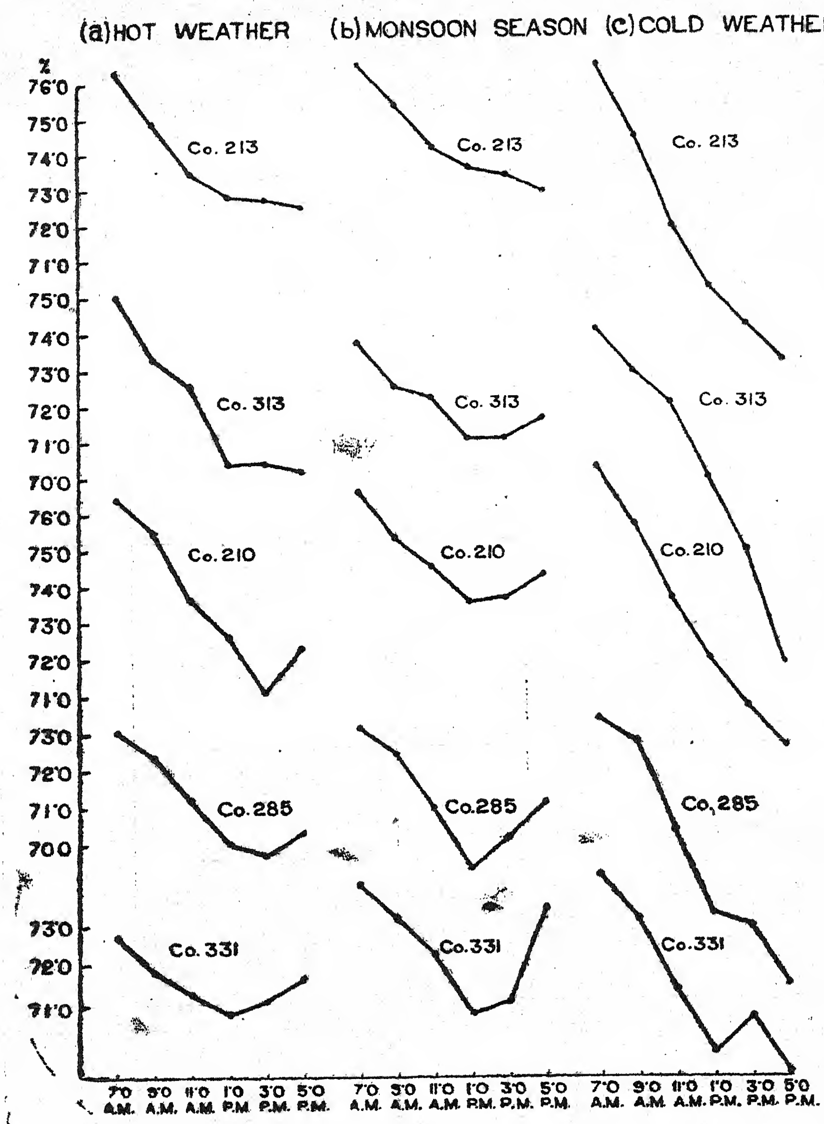

FIG. 1. Periodic variations in leaf moisture

TABLE II

Analysis of variance—hot weather series

Due to	Degree of freedom	Sum of squares	Mean variance	F^1/F^2
Varieties (V)	4	91·8903	22·9726	1·285
Dates (D)	2	106·5397	53·2698	2·979*
Two-Hourly Fluctuations (T)	5	157·1305	31·4261	1·758†
Interactions :				
V × D	8	10·8194	..	..
V × T	20	27·0639	..	..
D × T	10	5·4713	..	..
Residual error	40	715·1941	17·87985	..
Total	89			

* Significant at 10 per cent

† Significant at 20 per cent

Two-hourly fluctuations exhibited significant differences at 20 per cent level of significance. Still wider differences were apparent for mean values of leaf moisture on different dates which were significant at 10 per cent level of significance. The various first order interactions were not significant.

During the monsoon period, except variety Co213, the foliage of all the other varieties exhibited the maximum saturation deficit at 1.0 P.M. (Fig. 1b). This deficit was made up in the case of varieties Co285 and Co331 after 1.0 P.M., so that leaves had higher water content at 3.0 P.M. and 5.0 P.M. respectively. In the case of varieties Co313 and Co210 the deficit continued to exist till 3.0 P.M. Later the deficit was made up partially by 5.0 P.M. In general in the monsoon period varieties exhibited 2 per cent less water deficit than during the dry weather.

TABLE III

Two-hourly fluctuations in leaf moisture during the monsoon period

Time/Date	7.0 A.M.	9.0 A.M.	11.0 A.M.	1.0 P.M.	3.0 P.M.	5.0 P.M.
			Variety—Co213			
2/7	75·95	75·18	74·34	73·81	74·36	73·03
14/7	74·69	74·00	73·45	73·00	72·55	71·77
4/8	74·73	74·08	72·13	71·89	72·02	72·73
18/8	78·96	75·50	73·34	73·24	73·00	73·04
27/8	76·52	76·81	76·33	74·85	73·40	73·08
Mean	76·17	75·11	73·92	73·38	73·07	72·73
			Variety—Co313			
2/7	72·29	71·85	70·68	68·87	69·00	69·86
14/7	71·84	70·34	70·18	69·72	70·54	69·54
4/8	74·08	73·32	72·90	72·11	70·46	71·34
18/8	73·89	72·96	72·28	71·91	71·91	74·20
27/8	75·75	75·43	74·56	72·51	73·14	73·06
Mean	73·57	72·38	72·12	71·02	71·01	71·06
			Variety—Co210			
2/7	76·88	77·10	76·36	74·75	75·30	76·68
14/7	76·61	73·27	73·07	72·61	72·92	73·08
4/8	75·39	75·60	73·43	72·65	72·16	72·64
18/8	77·25	75·67	75·23	73·88	74·05	76·19
27/8	74·21	73·74	72·97	68·08	69·65	69·79
Mean	73·29	72·56	71·15	69·48	70·36	71·30
			Variety—Co331			
2/7	76·59	75·96	74·53	70·84	70·03	75·61
14/7	72·20	70·34	71·42	70·33	70·31	71·68
4/8	74·50	72·38	71·83	71·19	71·63	71·79
18/8	73·11	72·94	72·13	70·99	73·07	72·98
27/8	75·02	74·52	71·66	69·91	71·78	73·31
Mean	74·08	73·23	72·31	70·63	71·36	73·47

TABLE IV

Analysis of variance—monsoon series

Due to	Degree of freedom	Sum of squares	Mean variance	F^1/F^2
Dates (D)	4	76·119	19·02975	11·876*
Varieties (V)	4	238·047	59·51175	37·1368*
Intervals (I)	5	175·67	35·13	21·92*
Interactions :				
D × V	16	79·472	4·967	3·0996*
D × I	20	22·318	..	..
D × I	20	19·504	..	..
Residual error	80	128·202	1·6025	..

* Significant at 1 per cent level

The analysis variance of the data, given in Table III, was carried out (Table IV) which indicates significant differences amongst varieties in their mean leaf water content irrespective of the two-hourly intervals and dates of estimation of leaf water content. Similarly significant differences were observed amongst various dates irrespective of the effect of two-hourly fluctuations and the varieties. The interaction between varieties and dates was also significant, so that on different dates varieties showed different water content. On the whole the two-hourly intervals exhibited significant differences.

In the cold weather a progressive deficit in leaf water content was noticed as the day advanced. The rate of decrease from hour to hour was very much pronounced as compared to the preceding two seasons (Table V, Fig. 1C). This is evident from Table VI in which the analysis of variance of the data is given :

TABLE V

Diurnal variation in leaf moisture during the cold weather

Dates/Time	7.0 P.M.	9.0 P.M.	11.0 A.M.	1.0 P.M.	3.0 P.M.	5.0 P.M.
			Variety—Co213			
6/11	79·29	76·40	74·10	71·30	69·40	68·65
23/11	74·77	72·68	69·11	67·76	67·66	67·11
28/11	75·40	73·56	72·00	71·24	70·44	68·79
Mean	76·25	74·21	71·74	70·10	69·17	68·18
			Variety—Co313			
6/11	73·38	72·19	71·86	69·80	68·18	64·24
23/11	74·05	72·98	72·75	70·39	70·34	66·50
28/11	74·39	73·29	71·47	69·90	66·40	64·11
Mean	73·94	72·82	72·03	70·03	68·31	64·59
			Variety—Co210			
6/11	77·09	74·98	72·97	70·56	70·35	69·95
23/11	78·38	77·27	74·80	72·85	70·12	67·59
28/11	76·30	74·80	73·53	72·91	69·09	68·26
Mean	77·26	75·68	73·73	72·11	69·85	68·72

TABLE V—*contd.*

Diurnal variation in leaf moisture during the cold weather—contd.

Dates/Time	7.0 P.M.	9.0 P.M.	11.0 A.M.	1.0 P.M.	3.0 P.M.	5.0 P.M.
			Variety—Co285			
6/11	74·67	73·70	71·60	70·45	68·85	66·24
23/11	76·00	75·32	73·07	69·07	69·90	67·97
28/11	73·92	72·67	70·00	68·43	68·67	68·15
Mean	74·54	73·90	71·56	69·32	69·01	67·45
			Variety—Co331			
6/11	72·00	70·83	68·00	67·30	69·50	69·23
23/11	74·20	73·19	71·12	69·50	70·12	66·72
28/11	73·83	72·72	71·71	69·00	69·30	68·26
Mean	73·34	72·24	70·28	68·60	69·67	68·07
			Variety—Co299			
6/11	74·53	73·64	71·44	68·41	67·28	64·15
23/11	71·92	68·70	67·20	65·10	64·91	62·90
28/11	72·20	68·92	65·80	64·00	63·30	60·98
Mean	72·88	70·42	68·15	65·83	65·16	62·68
			Variety—Co281			
6/11	76·78	74·29	71·70	68·20	70·30	67·53
23/11	76·92	73·45	71·45	69·00	70·80	66·34
28/11	76·85	73·87	71·58	68·30	70·55	66·94
Mean	76·85	73·87	71·58	68·60	70·55	66·94
			Variety—Co356			
6/11	77·24	76·02	75·23	74·76	72·44	89·83
23/11	76·60	74·24	72·90	71·85	69·80	66·40
28/11	78·10	75·50	74·94	73·39	69·40	68·22
Mean	77·31	75·25	74·36	73·33	70·57	68·15
			Variety—Co326			
6/11	76·70	74·36	72·33	70·22	69·88	70·78
23/11	76·34	75·24	73·25	72·94	70·23	69·72
28/11	74·50	72·10	69·55	68·20	68·53	66·10
Mean	75·85	73·90	71·71	70·12	69·55	68·87

TABLE VI

Analysis of variance—cold weather series

Due to	Degree of freedom	Sum of squares	Mean variance	F^1/F^2
Dates (D)	2	23·625	11·8125	5·921*
Intervals (I)	5	1261·850	252·37	126·50*
Varieties (V)	8	399·011	49·876	25·00*
Residual error	146	291·2907	1·995	..
Total	161			

* Significant at 1 per cent level

The analysis exhibited highly significant differences amongst the two-hourly fluctuations. Similarly differences in the mean leaf moisture content during the day amongst the varieties were also observed to be highly significant. Considering all the varieties under study during this stage Co281 showed the maximum deficit of 12·89 per cent and Co331 least deficit of 7·19 per cent over the initial water content of varieties at 7·00 A.M. In the last column of Table VII the order of earliness in maturity of varieties has been shown. It will be observed that during the cold weather early varieties, namely Co299, Co281 and Co313, exhibited higher water deficit than medium-early or late canes.

Rate of water loss during the course of wilting

Darwin [1904], Darwin and Pertz [1912] and Knight [1917] noticed that on severing a leaf from the stem and allowing it to wilt, a temporary opening of stomata prior to closure following upon wilting occurred. Knight stated that the time that elapsed between seering the leaf from the plant and the opening of stomata varies considerably with different plants. Transpiration within certain limits followed the course of the opening and closing of stomata on leaves. Studies carried out on different varieties of cane during the hot weather exhibited this sequence in the rate of transpiration under low transpiration conditions of the laboratory (Fig. 2). At first there was a progressive fall with time to a minimum, depending upon the variety following which the rate of transpiration rapidly rose, but soon after there occurred a decline in the curve of all the varieties. It may be mentioned that some varieties exhibited greater loss during the process of wilting than others. The maximum loss was sustained by variety B. 6308 of all the varieties under test.

The results of experiments conducted during the monsoon are presented graphically in Fig. 3 of the text. Marked tendencies in the course of changes during the process of wilting were rather irregular in all the varieties and the behaviour completely differed from the previous period. In the monsoon season it appears the foliage do not have a greater reserve of water which on wilting may be available for transpirational loss. Combined experiments on changes in stomatal aperture of wilting plants and their rate of transpiration conducted by Knight (loc. cit.) indicated, a rough correlation with the magnitude of the increase of stomatal aperture. It is interesting to speculate on the changes which occur respectively to the stomata during the monsoon and the cold weather. Knight could observe no correlation between the temperature of the air and the magnitude of the accompanying increase in transpiration rate from the leaf surface. At the same time he found a distinct relationship between the temperature during the experiment and the length of the interval between the commencement of wilting and the occurrence of the maximum transpiration rate which approximately varied inversely with temperature. Evidently other factors than the temperature factor were responsible for the loss of unregulated transpiration during the process of wilting. Water content of leaf is a factor of importance in the process was clearly shown by Knight. During monsoon the plants have ample supplies of water at their disposal and they seldom suffer from shortage. The atmospheric relative humidity also remains high. The foliage are adopted to such conditions. They maintain water balance without suffering an acute water deficit. It is, therefore, that during the monsoon season the maximum deficit exhibited by any of the varieties is small, compared to the deficit either in the hot weather or cold season.

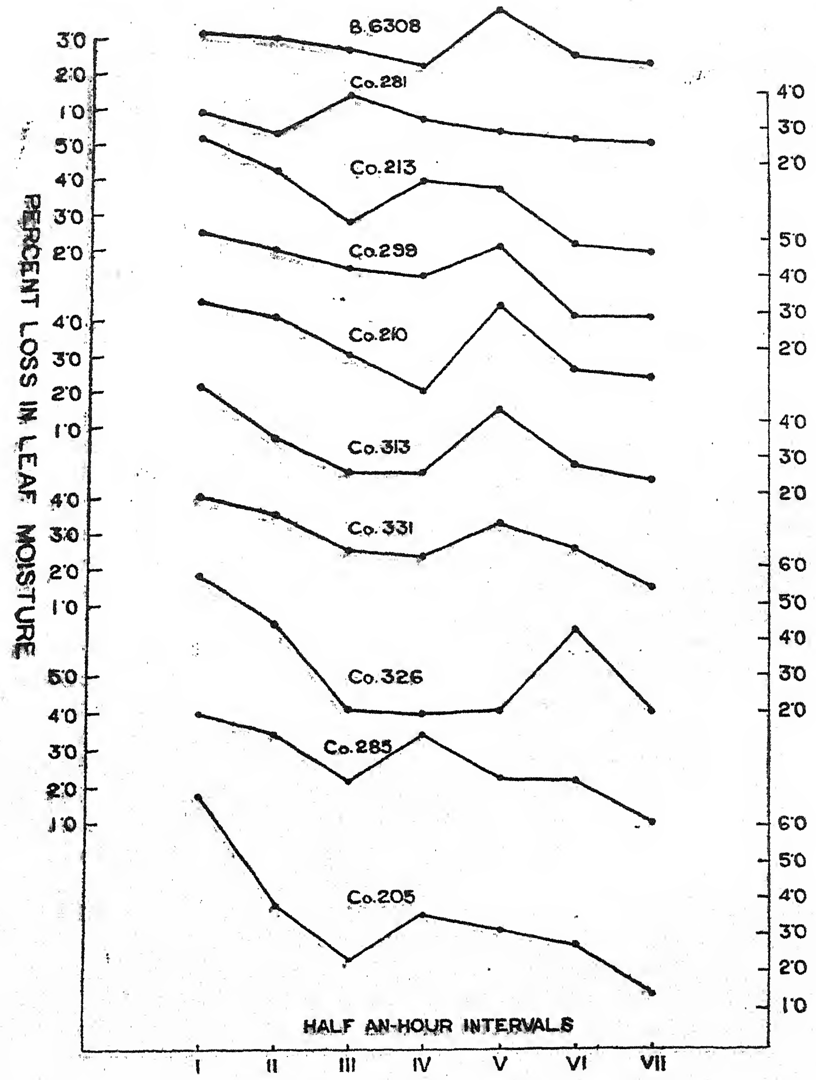

FIG. 2. The rate of water loss during the course of wilting : the hot weather series

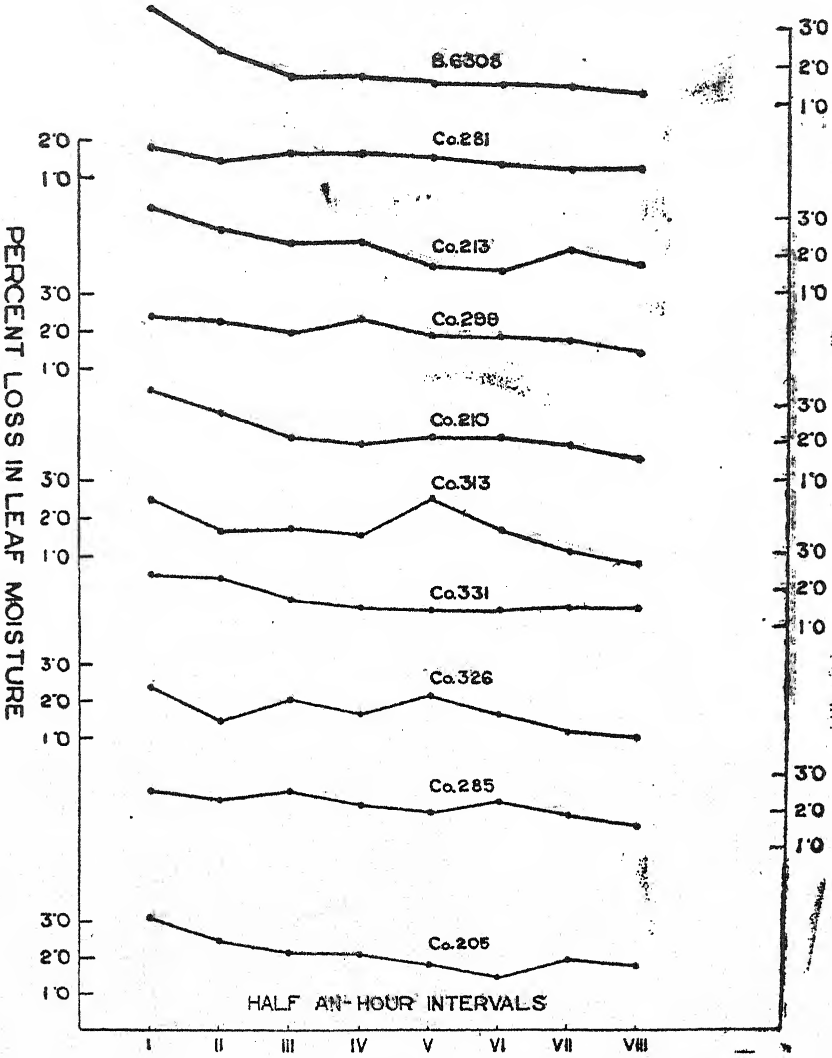

FIG. 3. The rate of water loss during the course of wilting: the monsoon series

So long as the plant experiences little shortage of water the whole regulating mechanism remains inactive and the march of transpiration passively follows that of the meteorological factors. No sooner the leaf cells experience a deficiency in water supply the turgor is lost and a tension equivalent to many atmospheres arises in the cells. This in turn is transmitted to the vessels. These, it is presumed, are compressed as they give up their water to the parenchyma of the leaf. This suction, developed in wilting leaves due to to the cohesive power of the water permeating the plant, is transmitted to all parts and acts as a powerful regulator of transpiration from the leaves [Maximov, 1929]. During the monsoon season, owing to the mild environment, the suction pressure in the leaf cells is not very great. If any deficit occurs, with a slight suction pressure equivalent to a few atmospheres, the loss is made good through the channel of vessels by the roots which have ample supplies of easily available water at their disposal. On the other hand in the hot weather or in the cold season the soil moisture is not so readily available with the result that a greater water deficit in the leaves is created during the afternoon hours. During the cold weather this deficit is greater because of larger transpiring area of the foliage of the crop than of the as yet comparatively smaller plants during the hot weather.

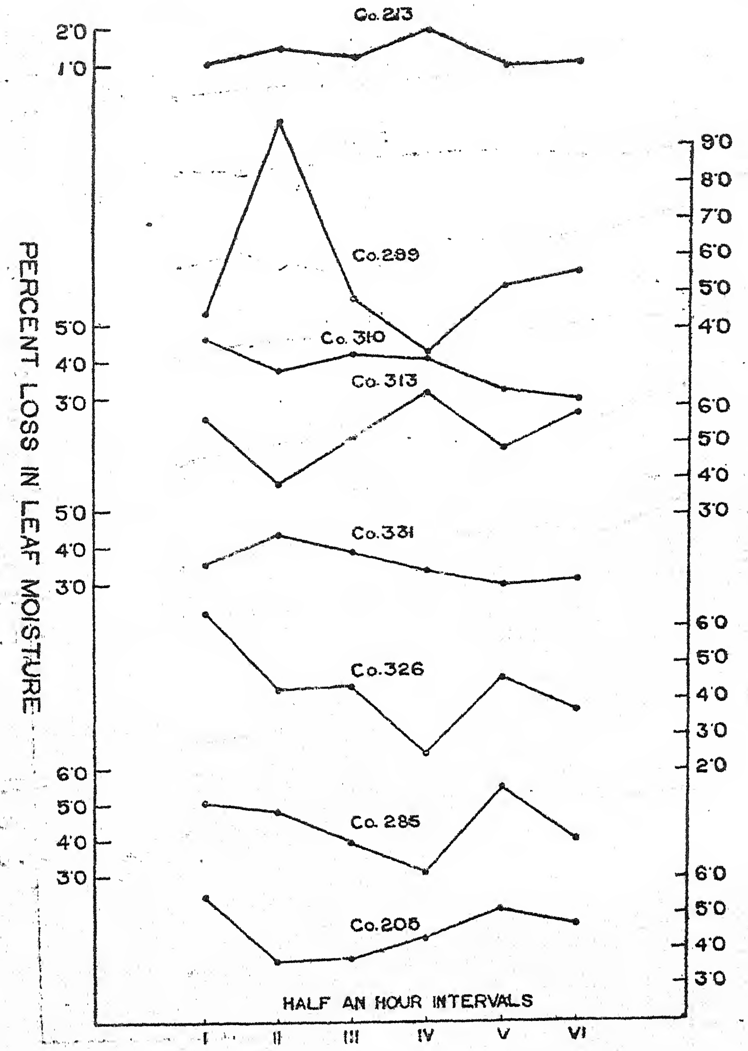

FIG. 4. The rate of water loss during the course of wilting : the cold weather series

Since during the monsoon period the leaves do not manifest high degree of moisture deficit, the available water for loss during the process of wilting is small and the leaves, when artificially wilted after severing them from the plant, did not exhibit the marked tendencies during the course of wilting. In fact the loss experienced from one interval of half hour to another was so small that abrupt rise and fall might not have been clearly exhibited. In the cold weather in spite of the leaves exhibiting high degree of moisture deficit, and thus high suction tension equivalent to a many atmospheres, other conditions upset the regulatory function of the stomata, and the deficit could not be made up in leaves till 5 P.M. Luthra and Chima [1937] while working on cotton noticed that during the month of November the transpiration-regulatory function of stomata was lost. Assuming that that happens with sugar cane stomata also, it is evident that in spite of the high suction developed within the vessels of the plant the deficit in leaf moisture is not made up towards the evening in the cold season, as it could be made up during the hot weather or monsoon period (Fig. 1).

Relative rate of transpiration from varieties in relation to environment

Before proceeding to give detailed data for transpiration it appears appropriate to give the data on foliage and root development for both are separate entities when absorption and transpiration are considered individually (Huber, loc. cit.). The mean dry matter weights of foliage and roots of the five plants of each of the varieties and the ratios between the two are given in Table VII.

TABLE VII

Foliage/Root ratios and relative transpiration ratios : Hot weather studies—dry weight in gm.

Particulars	Varieties.								
	Co285	Co281	Co299	Co210	Co213	Co331	Co326	Co313	Co205
Foliage—gm.	40·40	41·57	41·03	54·77	48·76	49·42	50·60	32·32	48·10
Roots—gm.	10·48	10·61	10·78	18·62	17·34	19·47	20·64	13·74	24·91
Mean water loss per day—gm.	231·65	285·20	142·78	266·18	389·10	399·31	480·70	237·22	513·22
Foliage/Root ratios . .	4·20	3·92	3·81	2·94	2·80	2·50	2·45	2·35	1·93
Relative transpiration ratios	5·26	6·86	3·48	4·86	7·98	8·08	9·50	7·34	10·67

Coefficient of correlation between foliage/root and relative transpiration ratios —0·68±0·1787

It will be observed that generally varieties which have high foliage/root ratios have low relative transpiration ratios. Statistical examination of the data revealed a fairly high significant coefficient of correlation between the two factors.

During the senescent phase of the cane crop when transpiration rate principally due to less intense environment, is low the results indicated similar trends. The data are presented in Table VIII.

TABLE VIII

Foliage/root ratios and relative transpiration of varieties during the senescen phaset of the crop—dry matter in gm.

Particulars	Varieties								
	Co285	Co326	Co213	Co299	Co313	Co281	Co331	Co205	Co210
Foliage wt.—gm. . . .	187·52	276·01	203·90	185·15	258·50	126·44	248·04	171·38	218·78
Roots wt. ,, ...	76·13	115·24	84·91	86·05	119·94	59·14	127·74	96·96	125·18
Foliage/root ratios . . .	2·47	2·40	2·40	2·18	2·15	2·14	1·94	1·76	1·74
Relative transpiration ratios .	4·44	3·66	7·26	4·05	6·46	6·15	6·02	5·25	7·26

Coefficient of correlation between foliage/root ratios and the relative transpiration ratios .. —0·722±0·1072 (significant at 5 per cent).

It is evident from the high value of the coefficient of correlation that the extent of root system like the foliage, plays an important part in regulating transpiration of the plant.

Maximov (loc. cit.) while explaining the mechanism of regulation of transpiration stated that investigations of Lloyd [1912], Livingston and Brown [1912], Muenscher [1915] and Knight [1922] had shown that stomatal aperture and transpiration did not show consistent interrelationship. In sugar cane Kuyper [1915] observed that the maximum rate of transpiration generally reached after the stomata had begun to close so that the transpiration rate was independent of the stomatal behaviour under the conditions of his experiments. Haines [1935] stated, that the water content of the leaf is one of the principal factors controlling the transpiration rate, the operating factor being the Pressure deficit which he defined as the difference between the pressure in the conducting tract and the pressure at the leaf surface. According to Miller [1938], these pressure deficits alone apparently cannot reduce transpiration by their effects upon the vapour pressure at the leaf

cell surfaces but must also cause an increase in the resistance to the flow of water through the protoplasts of the cells of the leaf. Two of the factors that apparently may greatly influence the degree of incipient drying in the leaf and thus influence its rate of transpiration are the leaf surface and the nature of the root system. Under the environmental conditions, when atmospheric aridity manifested its influence, the coefficients of correlation between foliage-root ratio and the relative transpiration ratios were fairly high and significant. Evidently foliage and roots in concert with each other play a significant part in regulating transpiration through the plant.

Rate of transpiration during the successive months of the maturition stage of the crop—

It is natural enough that the varieties should show an increased rate of water loss during the summer and active growing season. During the maturition stage when the plants enter into a state of senescence, bringing growth almost to a stand still, it appeared interesting to study the behaviour of varieties in respect of the transpiration rate month after month. The results (Table IX) indicate that relative transpiration ratio and the transpiration intensity decreased as the season advanced and varieties matured. Graphic representation of the data further revealed that early varieties, namely, Co299 and Co313 exhibited a more rapid decrease in the transpiration loss than the other varieties under experiment. These varieties within a period of one month i.e. in November showed a decrease of 20 per cent as compared to Co281, a medium early variety, which depressed the rate of water loss by about 10 per cent only. Other varieties maintained transpiration rate equal to their October values. In December early varieties had depressed their rate of loss to about 50 per cent while the mid-season ones kept up to about 70 per cent and higher of the October value. In January though all varieties indicated decrease the magnitude of depression was not as great as in the preceding month. Evidently the various varieties exhibited different behaviour as the season advanced. If environment were the factor mainly responsible then all the varieties should have exhibited equal depression in the rate of water loss as the season advanced and became cooler and cooler month by month. Obviously other factors intervened to cause a difference in the degree of depression in the rate of transpiration exhibited by varieties in the various months.

TABLE VIII

Relative transpiration ratios and transpiration intensities of varieties during senescent phase of cane crop

Varieties	Months	Relative transpiration ratios		Transpiration on foliage area basis	Intensities per cent of October value
		On foliage dry weght basis	per cent of October value		
Co299	October	4·05	100·0	0·155	100·0
	November	3·22	79·5	0·124	80·0
	December	2·16	53·3	0·083	53·7
	January	2·02	49·0	0·078	51·0
Co313	October	6·46	100·0	0·211	110·0
	November	5·12	79·3	0·167	79·1
	December	3·38	52·3	0·110	52·0
	January	2·48	38·2	0·095	45·0
Co281	October	6·51	100·0	0·147	100·0
	November	5·61	86·2	0·134	91·1
	December	4·31	62·2	0·103	70·1
	January	3·61	56·6	0·083	56·5

TABLE VIII

Relative transpiration ratios and transpiration intensities of varieties during senescent phase of cane crop

Varieties	Months	Relative transpiration ratios: On foliage dry weight basis	Relative transpiration ratios: per cent of October value	Transpiration on foliage area basis	Intensities per cent of October value
Co285	October	4·44	100·0	0·122	100·0
	November	·37	98·4	0·119	97·6
	December	3·06	68·9	0·083	64·3
	January	2·75	61·9	0·075	58·1
Co331	October	6·02	100·0	0·141	100·0
	November	5·08	84·4	0·133	97·8
	December	4·23	70·2	0·102	72·3
	January	4·19	69·2	0·098	69·5
Co210	October	7·26	100·0	0·136	100·0
	November	7·13	98·2	0·134	98·5
	December	5·68	78·2	0·107	79·4
	January	5·39	74·2	0·101	75·0
Co205	October	5·25	100·0	0·149	100·0
	November	5·20	99·0	0·149	100·0
	December	4·15	79·0	0·118	79·2
	January	3·73	71·0	0·107	71·8
Co213	October	4·41	100·0	0·152	100·0
	November	4·71	106·8	0·163	107·3
	December	3·65	82·8	0·126	82·9
	January	3·48	78·9	0·120	78·9
Co326	October	3·66	100·0	0·128	100·0
	November	4·05	110·7	0·142	110·0
	December	3·40	92·9	0·119	91·5
	January	3·24	88·5	0·114	88·4

GENERAL DISCUSSION.

In the words of Leake [1943], the capacity of any climate to support plant life depends on two factors, that which may be termed the energy level, of which a partial measure is the temperature and the moisture level of which the measure is rainfall. Failure in a crop is due to the fact that morphologically or physiologically it is not adapted to the range of these two levels occuring in the locality. However, the grower may manage to change the moisture level to suit the plant. But he is unable to change the energy level very materially. The water balance of the plant at any moment is 'the resultant of the interplay of all the factors, both internal and external, affecting its water balance'. Virtually the leaf moisture content at any given time during the day is determined by the rates of transpiration and absorption from the plant. When the former tends to be more rapid than the absorption from the soil, a moisture deficit in the leaf occurs, the degree of which depends upon the aridity of external environment. In our results (Tables I, II and III) the degree of moisture deficit during the mid-day hours in the hot weather and cold months was much greater than in the monsoon months. Further it was noticed that during the cold season when plant enters upon its senescent phase all the products of metabolism are not utilized for growth but a major portion of them is stored as carbohydrates. The rate of accumulation of sucrose in the cane plant thus increases. Some of the varieties store up sugar at a much faster rate than others and are fit to be crushed early. It was observed that not only the degree of saturation deficit increased very considerably in the autumn

months than that in the hot weather but early maturing varieties exhibited greater saturation deficit as compared with the mid-season or late canes. Besides, it was noticed that as season advanced the early or medium-early maturing varieties depressed their rate of transpiration much more than mid-season or late canes (Fig. 4). It is evident that an internal factor other than the general structure of the leaf or the external environment was affecting the saturation deficit and transpiration rate. Drabble and Drabble [1907] noticed that the concentration of sap must vary over a wide range in order that any appreciable influence may be exerted on transpiration rate. The difference in the concentration of sucrose content in the cell sap of the plants of early and mid-season and late varieties varies between 3 and 5 per cent. These differences had been sufficient to depress the transpiration rate by 20 per cent in the November month.

It was, however, noticed that Co285, an early maturing cane, maintained its transpiration rate in November equal to that in October. This exceptional behaviour may be explained on the basis of its drought resistant nature [Khanna and Venkatraman, 1929]. It has been shown by various workers such as Dunn [1933], Dexter, Tottingham and Garber [1930] that xerophytic plants posses higher content of hydrophyllic colloids which under conditions of drought develop high imbibition pressure and, therefore, retain high water content in the leaf and this was so in spite of the high concentration of cell sap in the stem which should cause greater water deficit in the leaves.

Weaver and Clements [1929] have stated, 'A complete scientific understanding of relationship between the soil and crop cannot be obtained until the mechanism is understood by which the soil and plant are brought into favourable relationship, i.e. root system'. Khanna [1934] has recognized three distinct types of root systems in sugar cane, namely, (a) mesophytic, (b) semi-xerophytic and (c) xerophytic. The classification is based primarily on the nature of vertical and horizontal spread of the root system in the soil. The varieties with mesophytic type of root system are less resistant to drought owing to more lateral spread, so that during the periods of drought the varieties suffer from low availability of water for maintaining water balance of the plant. During the hot weather and in the autumn months when the crop has to subsist on conserved moisture in the soil, the type of root system must play very significant part in the upkeep of leaf moisture, rate of transpiration, turgor, etc. A variety which is unable easily to adjust itself under these environmental conditions must of necessity fail. This conclusion is supported by the data on transpiration ratios and foliage/root ratios. Significant negative correlations were observed between the two entities under the summer and autumn conditions (Tables VII and VIII), the two stress periods in the environment of North Bihar.

Summary

Investigations on the water relations of sugar cane plant under the unirrigated conditions of North Bihar were conducted for better comprehension of the functional response and suitability of the cane varieties to the environmental conditions.

Experimental evidence indicated that early varieties, namely, Co281, Co299, Co313 and Co356 exhibited a higher saturation deficit after the mid-day hours than either the mid season or late canes. Maximum deficit was indicated in the autumn months and minimum during the monsoon period. The course of changes in the rate of water loss from the wilting leaves during the hot weather was normal, i.e. initial fall was followed once by a rapid rise and then a slow decline; during the monsoon such changes were less conspicuous and in the cold weather they were irregular in all the varieties. Foliage/root ratios and the relative transpiration ratios of the varieties during the hot weather and the autumn months exhibited high significant correlationship. During the latter season a successive decrease, month by month, in the relative transpiration ratios and transpiration intensities was exhibited by all the varieties. The early maturing ones depressed the rate of water loss to about 50 per cent of their October value in the month of January, while others kept up to about 70 per cent or higher of the initial values in October. The importance of extensive semi-xerophytic root system of the varieties for North Bihar soils has been indicated. The exceptional behaviour of Co285 in decreasing its relative transpiration ratio in the manner of early varieties and still maintaining high water content in the foliage is attributed to its drought resistant nature.

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THE RELATIVE EFFICIENCY OF WATER REQUIREMENTS IN RELATION TO MANURIAL TREATMENTS*

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SOIL fertility is a critical factor limiting growth of plants. One of the basic essentials of any crop for successful growth and development is its nutrient requirements. It is not merely the application of one single element such as nitrogen and its effect that are required to be studied but the working out of a well balanced nutrient schedule is the primary need. This schedule should necessarily ameliorate or lessen the deficiencies of available plant nutrients, should produce apt physical changes in the soil base and should conduce to elaboration of nutrient salts in an assimilable form ; otherwise the application of fertilizers is bound to be wasteful because of the failure to take the circumstances fully into account. This is specially true of nitrogen fertilizers as it is subject to more rapid depletion than others. It is the purpose of this note to demonstrate the effectiveness of the different manurial schedules, time of their application, form in which nitrogen should be applied and to express this effectiveness mathematically in terms of relative efficiency of water requirements.

There is available a mass of data bearing on the response of crops to application of fertilizers as measured by final harvest yields but there is generally a paucity of information on the effects of the application of fertilizers to soil on the several functional responses of plants. McCool [1928] showed that the application of potash and phosphoric acid resulted in an appreciable increase in the concentration of cell sap and that when phosphoric acid was used it had a tendency to bring about a reverse action. He also stated that leaves of plants dried out (wilted) more rapidly when grown on soils without fertilizers than on soils to which fertilizers had been added which difference he assumed to be due to differences in the concentration of cell sap. Leather [1912], Kiessalbach [1916] and Singh and Mehta [1938] have shown that transpiration ratios of crops are lowered by manurial treatment. Raheja [1934], besides confirming the above conclusions, observed that wheat crop manured with farm yard manure made more economical use of water than that manured with an equivalent dose of ammonium sulphate. Sethi [1936] reported that under conditions obtaining at Shahjehanpur optimum returns in cane yield were obtained with a considerably low water duty when nitrogen fertilizer was applied at the rate of 100 lb. per acre. Rege, Yaghoklar, Wagle, Apte and Kulkarni [1943] have investigated on a field scale, the water requirements of sugar cane crop in relation to manurial tretaments. They observed that the interaction between nitrogen application and water duty was significant, indicating the value of higher manuring with higher irrigation.

Leather [1907] and later on Davis [1918] pointed to the deficiency of phosphates in North Bihar soils and stressed the need of application of phosphoric acid as a fertilizer. Cliff [1931] concluded from the data of trials extending over three seasons, 1928-29 to 1930-31, that a dressing of 40 lb. nitrogen and 50 lb. phosphoric acid gave substantial and significant increase in yield in every case over the control series. The manures, however, were applied in two doses, one half at planting and the other half at earthing up of the crop, that is with the first break of the monsoon. These findings were further confirmed by Cliff [1937] and it was pointed out that with a normal crop of sann hemp (Crotolaria juncea), buried as green manure during the preceding monsoon and with one maund of double superphosphate applied at planting, the need for the first half dose (20 lb. of N and 25 lb. of P2O5) was obviated. Cliff, however, could not decide as to whether to apply the manure in one dose or in two half-dozes. Recently Yuen and Borden [1937] have shown that cane plant can rapidly absorb from the soil available nitrogen and the quantity of nitrogen absorbed is independent of the needs of plant which when absorbed beyond the requirements at the moment might be stored up and used for subsequent growth.

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* Read at the 1940 meeting of the Indian Science Congress Association.

Methods and experimental scheme

The experiments hereinafter described were conducted in auto-irrigators. The method of determining water requirements in auto-irrigators has already been described by the authors [1937]. Manurial doses applied were calculated on the surface area basis of the containers and were applied as per scheme of experiments described later in the text. The manures to be applied at planting were spread on the surface and the soil worked up to a depth of 6 in. to thoroughly incorporate the manure within the zone in which the set was to be planted. The recording of water day by day supplied by auto-irrigation system was then taken up. The manuring at earthing was done through the system of auto-irrigation.

Two sets of experiments were conducted. The first set consisted of studies for determining the effect of the application of inorganic fertilizers in relation to relative efficiency of water requirements and the second related to the study of the effect of castor cake & super when it replaced Niciphos II in the ordinary dose recomemended by Cliff [1931]. Besides, the object of these experiments was also to determine if the total quantity of manure applied in one dose at planting was more beneficial than when applied in two half-doses, that is one half at planting and the remaining half at earthing up of the crop. The treatments in the first set consisted of various dozes of inorganic manures as shown in Table I.

Table I

Scheme of inorganic manurial series

Pot No.	Notation for treatment	Treatments per acre in Lbs.						Remarks
		At planting N $P_2O_5K_2OB$			At earthing up N P_2O_5 K_2O			
1-4	A	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	Nitrogen was applied as ammonium sulphate; P_2O_5 as superphosphate and boron as boric Acid.
5-8	B	40	50	0 0	*nil*	*nil*	*nil*	
9-12	C	20	25	0 0	20	25	0	
13-16	D	40	50	80 0	..	..	..	
17-20	E	20	25	40 0	20	25	40	
21-24	F	40	50	80 0	*nil*	*nil*	*nil*	

Planting for this series was done as early as the middle of February and the shoots were visible on the soil surface within 18 to 20 days of planting in all the containers.

The treatments in the second set of experiments planted a fortnight later are given in Table II.

Table II

Scheme of organic versus inorganic fertilizer series

Pot. No.	Notation for treatment	Treatments per acre in Lbs.				Remarks
		At planting		At earthing up		
		N	P_2O_5	N	P_2O_5	
1-4	P	*nil*	*nil*	*nil*	*nil*	Niciphos II was selected as it has equal proportion of N and P_2O_5.
5-10	Q	22	22	22	22	
		(Applied as Castor cake and super)				
11-14	R	44	44	*nil*	*nil*	
		(Applied as castor cake and super)				
15-18	S	(As castor cake and super)		(As niciphos II)		
19-22	T	22	22	22	22	
		(Applied as Niciphos II)				
23-28	U	44	44	*nil*	*nil*	
		(Applied as Niciphos II)				

In this case also the plants appeared above ground within 20 days of the planting. The growth of plants was normal in the containers in both the series which were harvested in early February next year when their dry weights were determined. Simultaneously the total amount of water expended by each of the plants was worked out. In the calculation of the relative water requirements under various treatments root-weights were not taken into account because these studies were conducted to conform to the manurial experiments in progress in the field where root-weights were not possible. The bearing of these results will be discussed in a later publication when confirmatory results from further experiments in the field have been obtained by the senior author.

Experimental results

The results from the inorganic fertilizer series show (Table III) that in order of merit, the treatments, D,B,E,C, and F respectively indicate higher relative efficiency of water requirements as compared to the treatment A.

This evidently suggests that the application of fertilizers is beneficial in increasing the relative efficiency of water requirements.

Table III

Relative efficiency of water requirements in the inorganic manure series

Serial No.	A No manure (Control)	B 40 lb. N+50 lb. P_2O_5 in one dose at planting	C 40 lb. N+50 lb. P_2O_5 in two half dozes, each at planting and earthing	D 40 lb. N+50 lb. P_2O_5+80 lb. K_2O at planting alone	E 20 lb. N+25 lb. P_2O_5+40 lb. K_2O at planting and same at earthing	 40 lb. N+50 lb. P_2O_5+80 lb. K_2O_5+10 lb. boron at planting alone
I	293·0	195·0	165·7	172·8	175·5	210·0
II	255·7	175·9	240·0	200·1	173·7	153·5
III	193·2	183·4	219·5	181·4	..	216·7
IV	283·8	199·8	177·7	167·5	223·2	241·9
Mean	256·4	191·1	200·7	180·5	192·4	205·5
S. E. of difference between two treatment means		..	..	±17·46	..	..
Relative efficiency of water requirements	1·000	1·342	1·278	1·421	1·333	1·248

A comparison of treatments D and B and treatments E and C brings out the fact that application of potash, whether it was applied in one dose at planting or in two half-doses, improves the relative efficiency of water requirements. The effect of boron, however, is to depress the efficiency of water requirements, as the comparison of the mean values for F against B, C, D and E indicates. It is also apparent from a comparative study of the mean values of treatments B and C and treatments D and E that the application of the fetilizers in two half-doses is not conducive to economical use of water by the plants.

In the organic versus inorganic manure series (Table IV) a comparison of treatments P against R, U, Q, T and S shows that manurial treatments in this experiment also increased the relative efficiency of water requirements. Therefore in general the experimental results of the first and the second series corroborate each other.

TABLE IV

Relative efficiency of water requirements in the organic versus inorganic fertilizers series

Serial No.	P No manure (Control)	Q Castor cake+Super-22 lb. N +22 lb. P_2O_5 at planting and same at earthing up	R Castor cake+Super-44 lb. N+44 lb. P_2O_5 at planting alone	S Castor cake+Super 22 lb. N+22 lb. P_2O_5 at planting and Niciphos II-22 lb. N+22 lb. P_2O_5 at earthing	T Niciphos II-22 lb. N+22 lb. P_2O_5 at planting and same at earthing up	U Niciphos II-44 lb. N+44 lb. P_2O_5 at planting alone
I	194·7	144·8	180·5	226·1	257·1	148·4
II	332·4	188·1	168·5	209·8	250·0	543·3*
III	247·5	272·9	150·3	246·2	236·1	174·8
IV	244·4	299·1	178·7	232·1	187·4	155·7
V	*nil*	*nil*	146·5	*nil*	*nil*	185·2
VI	*nil*	*nil*	153·3	*nil*	*nil*	194·7
Mean	254·8	226·2	162·9	228·6	232·7	171·8
S. E. of difference between two treatments means				±22·41	..	..
Relative efficiency of water requirements	1·000	1·016	1·411	1·005	0·892	1·338

Further study of mean values of different treatments shows that the single dose at planting is superior to the two half doses, applied half at planting and remaining half at earthing up, in both the organic and the inorganic schedules of manuring. This is evident from the comparison of treatments R and Q and treatments U and T. The organic schedule of manuring is also slightly better than the inorganic one under discussion (Compare mean values of treatments R and U and treatments Q and T).

The analysis of variance of the results as worked out for the first set of experiments is given in Table V.

TABLE V

Analysis of variance : *Inorganic manure series*

—	Degrees of freedom	Sum of squares	Mean variance	Value of F	
				Observed	Theoretical at P=0·05
Treatments	5	14442·22	2888·44	2·99	2·81
Errors	17	16429·96	966·47		

From the analysis it is evident that differences amongst the treatments were significant at 5 per cent level of significance, lending further support to the conclusions reached above that manurial treatments gave higher efficiency of water requirements than no manure treatment. The analysis of variance of the data presented in Table IV, is given in Table VI.

TABLE VI

Analysis of Variance : Organic versus inorganic fertilizer series

—	Degrees of freedom	Sum of squares	Mean variance	Value of F	
				Observed	Theoretical at P=0·05
Total	26	64559·41			
Between treatment means	5	32921·008	6584·2016	4·36	4·04
Residual error	21	31638·402	1506·5906		

For purposes of analysis figure 543·3 relating to U treatment (Table II) was rejected on account of its abnormality. The analysis indicates significant differences amongst the treatments. Full dose application of organic or inorganic schedule of manuring shows definite decrease in the absolute water requirements of the plants. The split up dose though apparently indicates a decrease, the difference between the control and treatments Q, S and T is not wide enough to show significance.

Significance of the results

Willcox [1930] maintains that crops not only require the amounts of nitrogen or other minerals that are taken to build up the tonnage of the crop but these must be present in the soil to create a sort of pressure (*satiation pressure*) that forces the vegetative cells to go through their functions. From this it readily follows that manurial value of those fertilizers, as are resorbed immediately, is much higher than those which do not readily do so. Further indirect evidence to support this view has been given by Truog [1928] who describes solid phase feeding by plants in part to make up defficiency left over in the liquid phase feeding of the crop. Solid phase, feeding applies to such manures as are not directly absorbed and have residual effect. With these therefore, satiation pressure in the soil always remains effective and the cells remain more active than would otherwise be the case with manures that are quickly absorbed. In the second set of experiments organic manure (castor cake) that leaves its residual effect and therefore meets the requirements of satiation pressure and solid phase feeding, increases the efficiency of water requirements compared to the artificials.

Ayres [1937] has shown that maximum requirements of the crop for the mineral matter are in the early stages of growth of the crop. The experimental evidence from both these sets of experiments supports this contention. It seems to be the reason why a full dose applied at planting is more beneficial than the two half doses. A full dose at planting by creating higher satiation pressure in early stages is likely to induce better development of plants which ultimately results in higher efficiency of water requirements. The results of these experiments if confirmed by field experiments will have considerable agronomic value in saving the cost involved in making the second application of manure to the sugarcane crop.

The significance of boron in agriculture has been dealt with by Dennis and O'Brien (1937) in a monograph. Russel [1937] from the evidence of Terilokowski and Nowicki [1933] points out that '.........quantities in excess of the very small amounts needed by plants are harmful' and this probably explains why the plants did not show increased efficiency of water requirements. Since the quantities suggested are too small it may not be possible to work out the effect so clearly unless the experiments are specially laid out for the purpose.

Summary

The results of water requirements studies obtained from two sets of experiments reported above may be summarized as under:

(1) The complete manurial dose, whether it belonged to organic or inorganic schedule, applied all at the time of planting made the plants more economical in the use of water than the cases in which this manure was applied in two half-doses, that is half applied at planting and the remaining half at earthing up or in which no manure was applied.

(2) The application of Niciphos II was less economical from the point of view of water expenditure than an equivalent dose of castor cake.

(3) The application of potash reduced the water expenditure per unit of dry matter produced.

(4) The application of boron did not compare favourably with the in standard schedule (40 lb. N+50 lb. P_2O_5) though the plants showed better results than the ones in no manure series (control) which were least economical from water expenditure point of view.

(5) The application of fertilizers in general gave statistically significant increase over no manure in the relative efficiency of water requirements as compared to non-manurial treatments.

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THE QUALITY OF THE DRAIN, RIVER AND CANAL WATERS OF THE PUNJAB

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(With six text figures)

With the development of canal irrigation and the consequent rise of water-table in the Punjab has arisen the question of drainage. The two doabs which have been primarily affected by water-logging are Chaj Doab and Rechna Doab. The Chaj Doab lies between the rivers Jhelum and Chenab, and the Rechna Doab lies between the Chenab and the Ravi.

Figs. 1 and 2 show the main, the branch and the subsidiary drains of the Chaj and Rechna Doabs respectively.

The Chaj Doab

The main drainage systems of the Chaj Doab are the following:

1 Wan Drainage System

2 Raniwah Drainage System

3 Mona Drain

4 Lower Rani-wah Drain

1. *The Wan Drainage system*

This is a net work of several small drains forming a more or less complete circle which drains the area between the Chenab escape on the north-east side and the Southern Branch, Lower Jhelum Canal on the north-western portion. The total catchment area is equal to 28 square miles.

2. *The Raniwah Drainage System*

Towards the Jhelum side, the main natural drainage starts north-east of the town of Miani and travelling parallel to the river, discharges into it.

3. *The Mona Drain*

It starts from the right side of the Main Line, Lower Jhelum Canal. It pours its water into the Sulki Creek which in turn joins the river Jhelum. The total catchment area of the Mona Drainage System is approximately 476 square miles.

4. *The Lower Rani-wah Drain*

The Lower Rani-wah Drain has its beginning in the Bhek Main Drain which starts near R.D. 65,000 of the Sulki Branch, opposite the point where the Mona Drain enters the Sulki Creek. The total catchment area of the Lower Rani-wah Drain is approximately 301 square miles.

The Rechna Doab

The system of drainage that had developed to any large extent in this Doab was the Vagh Nallah. The total catchment area of this system is approximately 450 square miles.

As the programme for the construction of drains developed, the question of disposal of the drainage waters usefully became essential. One method that readily suggested itself was to mix the drain waters with the canal waters. This required a check on the quality of the mixed water so that the total salts do not exceed the suitability limit.

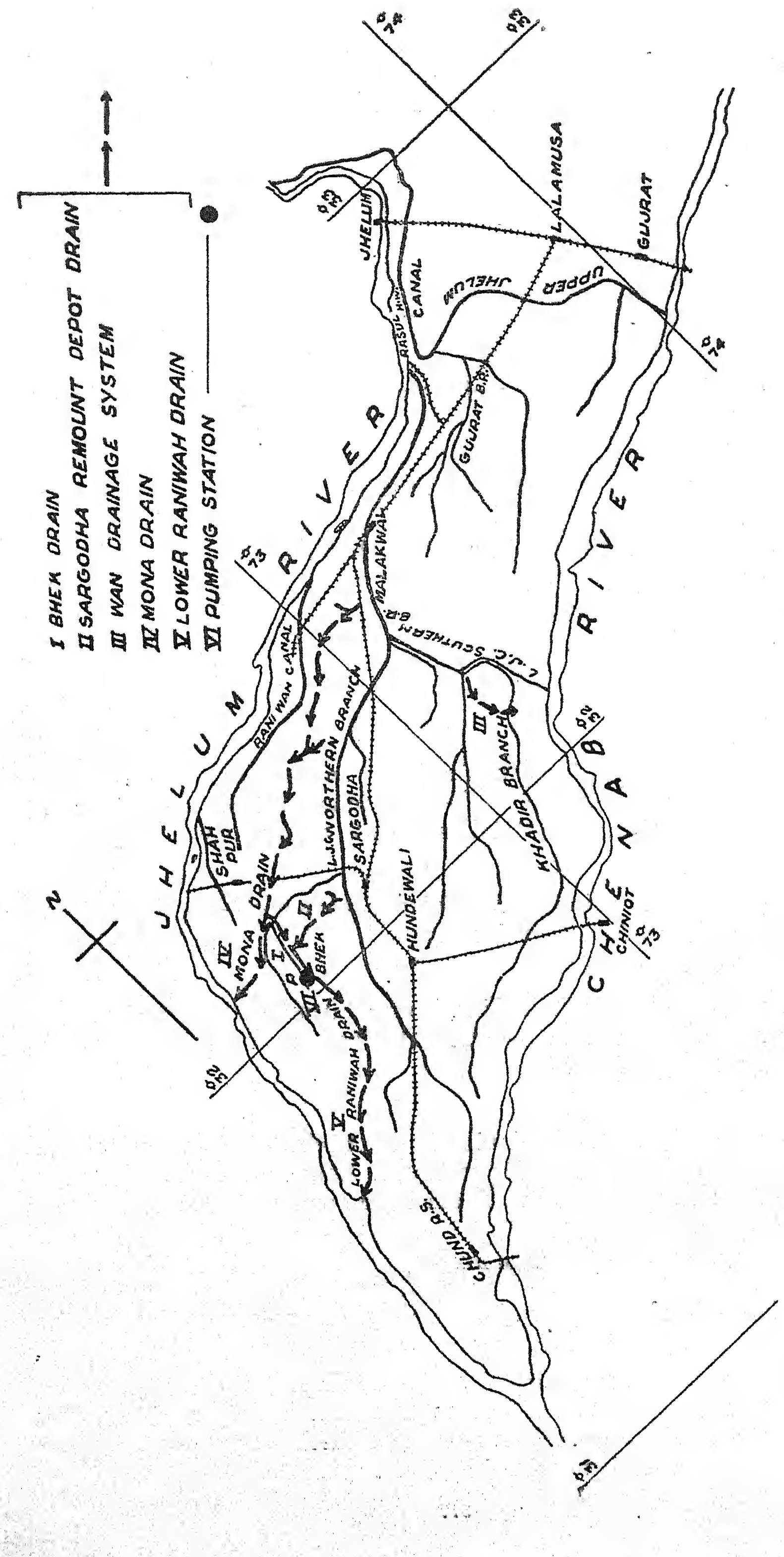

FIG. 1. The main, the branch, the subsidiary drains of the Chaj Doab

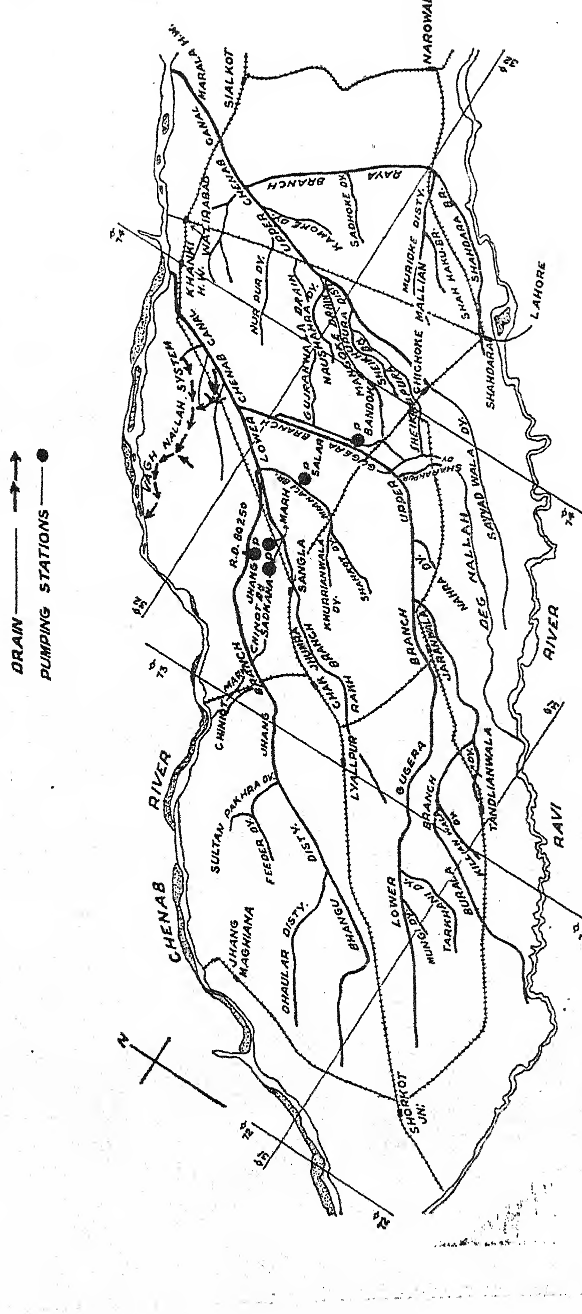

FIG. 2. The main drains & the pumping stations of the Rechna Doab

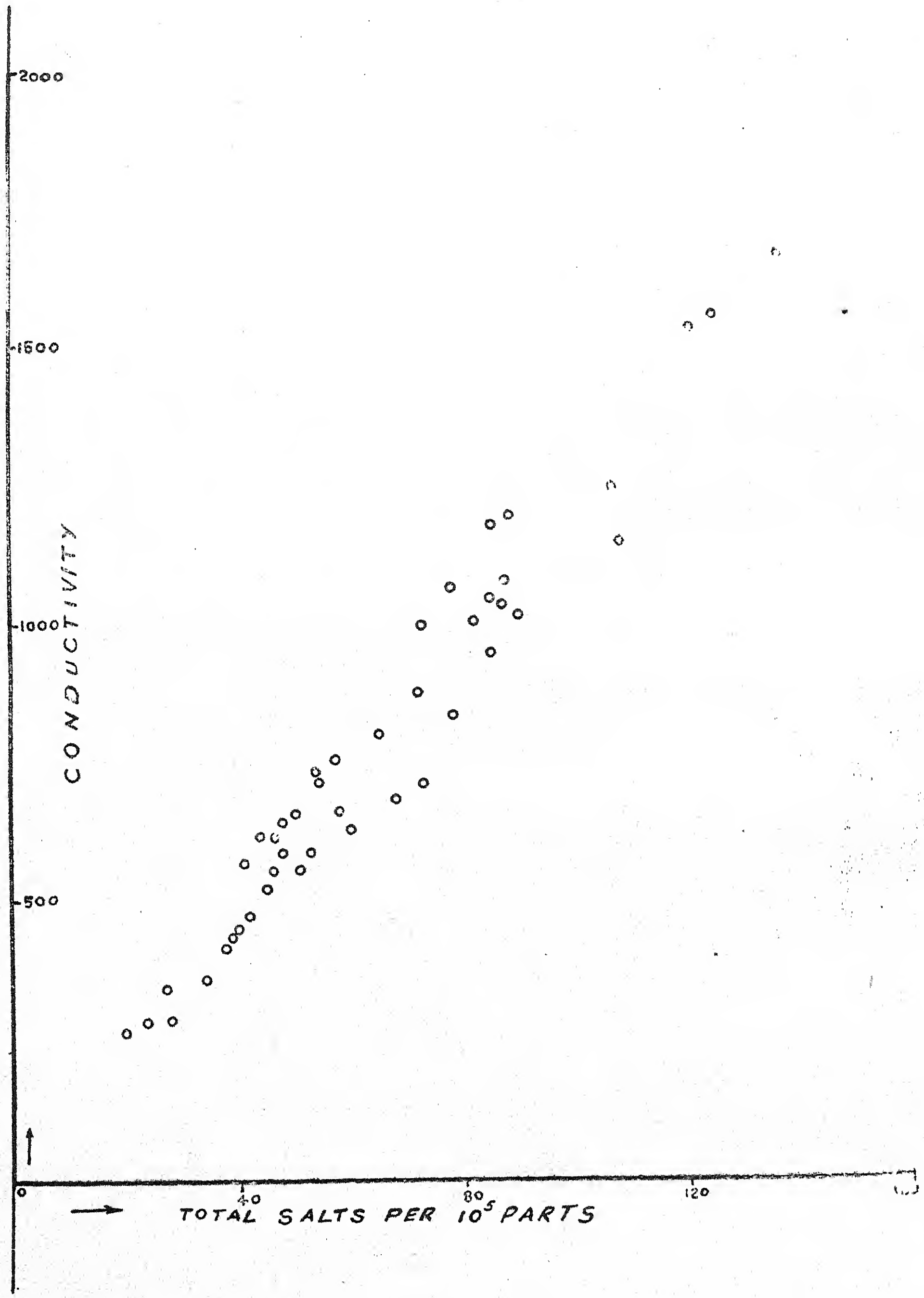

FIG. 3. The relation between conductivity and total salts of the drain waters

EXPERIMENTAL

A regular analysis of the waters of the major drains was started in 1933 with the following points in view:

a. Is the water fit for irrigation?

b. Are there any changes in the salt content of the water with the passage of years?

c. How far the drains are responsible for removing the salts from their catchment areas?

The waters were analyzed in the laboratory according to the usual method of analysis, and the results interpreted *vide* Taylor, Puri and Asghar [1935].

The standard for the suitability of water for irrigation purposes at present is that water containing 60 parts of salts per 100,000 parts of water is fit for irrigation, but if the water contains 60 to 120 parts of salts, the salt index should be determined according to the equation given below:

Salt index=(Total sodium—24·5)—(Total calcium—calcium in calcium carbonate) $\times$ 4·85.

The salt index is negative for waters fit for irrigation and positive for waters unfit for irrigation. The upper limit beyond which the water is generally declared to be unfit for irrigation purposes is 120 parts of salts per hundred thousand parts of water.

DISCUSSION OF RESULTS

(a) *Relation between conductivity and salt content of the drain waters*

Examination of water samples from various drains has been in hand for many years. The results of analysis of water (having total salts less than 160·0 parts per 100,000) are plotted in Fig. 3. The correlation of total salts with conductivity is positive and is 0·90 which is highly significant. The regression equation is y=0·08 x +3·0 where x = conductivity and y=total salts per 100,000 parts. The actual and the calculated values for a few drains are given in Table I. The agreement is excellent.

TABLE I

The agreement between the experimental and the calculated values of total salts of the drain waters

Serial No.	Name and site of the drain	Conductivity	Total Salts per 100,000 parts	
			Experimental	Calculated
1	Wan drain at R.D.O.	610	45·6	51·8
2	Wan drain (Pumping station)	565	40·9	48·2
3	Wan drain at R.D. 37,500	637	48·0	59·0
4	Mixture of Wan drain and Khadir Branch	260	19·6	23·8
5	Lower Rani-wah drain at R.D. 42,000	9,162	722·0	737·0
6	Lower Rani-wah drain at R.D. 238,500	6,351	467·5	511·0
7	Lower Rani-wah drain at R.D. 228,364	7,694	619·5	618·5
8	Mona drain at R.D. 13,200/14,000	991	743·8	795·8
9	Mona drain at R.D. 135,500	995	72·7	82·6
10	Mona drain at R.D. 327,500	1,095	78·0	87·7
11	Mona drain at Sulki creek	1,171	84·9	96·7
12	Tail Jhattanwali drain	443	40·1	38·4
13	Tail Kalerwali drain	625	60·4	53·0
14	Tail Shari drain	353	34·0	31·2
15	Tail Gajargola drain	750	57·5	63·0
16	Tail Said Nagar drain	1,000	32·2	83·0
17	Tail Bucha drain	1,098	107·5	90·8
18	Head Ahmed Pur Wagh drain	468	41·5	40·4
19	Ahmedpur Wagh drain at R.D. 30,000	582	52·95	49·6
20	Tail Ahmedpur Wagh drain	681	53·6	57·5
21	Tail Sagar Branch drain	344	27·3	30·5
22	Tail Ramgarh Nawan drain	610	44·0	51·8
23	Tail Hafizabad drain	1,034	86·4	85·7

TABLE I—*contd.*

The agreement between the experimental and the calculated values of total salts of the drain waters—contd.

Serial No.	Name and site of the drain	Conductivity	Total Salts per 100,000 parts	
			Experi-mental	Calculated
24	Tail Chammi drain	1,668	135·6	136·4
25	Tail Karyala drain	710	54·0	59·8
26	Tail Ratteki Drain	410	39·0	35·8
27	Tail Thatta Raika drain	430	39·0	37·4
28	Ahmedpur Kot Nikka drain R.D. at 50,000	710	73·2	59·8
29	Ahmedpur Kot Nikka drain at R.D. 17,000	684	67·5	57·7
30	Head Jurian Kassoki drain	286	27·6	25·9
31	Tail Jurian Kassoki drain	517	44·8	41·4
32	Salar drain at R.D. 30,000	578	48·1	49·2
33	Marh Salar drain at R.D. 79,000	552	46·3	47·2
34	Melowana drain at R.D. 2,000	1,013	90·3	89·0
35	Sukheki drain at R.D. 2,000	3,008	225·6	243·6
36	Sukheki drain at R.D. 1,000/3,000	2,742	270·0	222·4
37	Vanir drain at R.D. 1,000	2,430	181·9	197·4
38	Dabora drain at R.D. 100	3,688	314·6	298·0
39	Marh Chiniot at R.D. 165,000	1,075	87·4	89·0
40	Marh Chiniot Main drain at R.D. 125,000	1,513	119·8	124·0
41	Marh Chiniot at R.D. 16,000	1,554	124·3	127·3
42	Tail Kutreka drain	2,494	205·6	202·5
43	Rechna seepage drain at R.D. 5,000	283	24·1	25·6
44	Rechna Seepage drain at R.D. 30,000	555	50·8	47·4
45	Rechna seepage drain at R.D. 56,000	997	84·6	82·8
46	Gujranwala drain at R.D. 1,000	652	58·0	55·2
47	Tail Mangoki drain	877	72·4	73·2
48	Sheikhupura drain at R.D. 2,000	1,240	96·5	102·2
49	Tail Dhilwan drain	833	77·9	69·6
50	Tail Rechna outfall drain	946	84·6	78·7
51	Tail Jagatan drain	650	50·0	55·0
52	Tail Chakhni drain	800	69·6	67·0

(b) *Suitability of water for irrigation purposes*

The water of the Wan drain is generally fit for irrigation purposes. It has been noticed that sometimes the salt content rises above the safe limit of 60 parts per 100,000 but then the mixed water of the drains and the Khadir branch is suitable. The waters of the lower Rani-wah drains are unfit for irrigation. Where the total salt content exceeds the safe limit of suitability, it is to be mixed with canal water in order to bring down the total salts within the permissible limits.

The results of analysis of the canal waters are given in Table II.

TABLE II

Composition and concentration of salts in the waters of the Punjab rivers and canals

Sampling site	Salt Contents Calcium		(Parts per 100,000) Sodium			Total	Conduc-tivity
	Sulphate	Bicarbo-nate	Sulphate	Bicarbo-nate	Chloride		
Western Jumna Canal near Abdulla-pur	4·8	10·0	1·9	..	1·8	18·5	260
River Sutlej near Pillaur	3·4	16·0	3·2	..	2·3	24·9	325
Sirhind Canal near Doraha	4·4	11·0	3·9	..	2·3	21·6	325

TABLE II—*contd.*

Composition and concentration of salts in the waters of the Punjab rivers and canals—contd.

Sampling site	Salt Contents Calcium		(Parts per 100,000) Sodium			Total	Conductivity
	Sulphate	Bicarbonate	Sulphate	Bircarbonate	Chloride		
River Beas near Dhilwan	7·5	11·0	..	..	3·5	22·0	260
Upper Chenab Canal near Chichoki Mallian (U.C.C.)	..	10·0	11·4	1·1	2·9	25·4	275
Upper Bari Doab Canal near Tibri (U.B.D.C.)	3·4	7·0	3·6	..	1·8	15·8	200
Lower Gugera Branch, Lower Chenab Canal near Jaranwala (L.G.B.)	8·8	11·5	1·4	..	2·3	24·0	250
Lower Jhelum Canal near Ludewala (L.J.C.)	3·4	15·0	3·6	..	4·7	26·7	340

The results show that the conductivity and the total salts in parts per 10^5 parts range between 200 and 340 and 15·8 and 26·7 respectively. The L.J.C. water possesses the highest and the U.B.D.C. the lowest figure. The average ratio of conductivity to the total salts is 11·2. The average calcium/sodium ratio is 3·2. The highest ratio is found in L.G. and the lowest in U.C.C. The U.C.C. contains the highest concentration of sulphate ions, which is all sodium sulphate, and hence shows the lowest calcium/sodium ratio.

Calcium sulphate is present in the water of all the other canals.

All the waters are fit for irrigation.

Taking into consideration the average salt content during the past years, the dilution required to render the unsuitable drain water suitable for irrigation may be done according to Table III.

TABLE III

The dilution required with the canal water to make the drain water suitable for irrigation purposes

Serial No.	Name of the drain	Site	Mean discharge	Total salts in 10^5 parts	Dilution times to lower the salt content in 10^5 parts to		
					30 parts	60 parts	100 parts
1	Lower Rani-wah drain	R.D. 42,000	..	879·8	141·7	22·8	10·3
2	Mona drain	R.D. 327,000	..	284·8	42·5	6·2	2·4
3	Mona drain	R.D. 135,000	20·0	72·0	7·0	0·33	..
4	Wan drain		10·0	48·5	3·1	..	..
5	Sukheki drain	R.D. 3,000	2·9	288·8	43·1	6·4	2·5
6	Chiniot drain	R.D. 181,000	41·0	80·5	8·4	0·57	..
7	Chhami drain	R.D. 1,000	4·5	134·2	17·4	2·1	0·45

(c) *Changes in salt content with the passage of years*

The rate of increase in the total salts of some of the drain waters with the passage of years is incorporated in Table IV. The salt content of lower Rani-wah drain is increasing at the rate of 71·5 parts per 10^5 parts and 29·8 parts per 10^5 parts per annum at R.D. 42,000 and R.D. 238,500/228,364 respectively. The other drains do not exhibit any appreciable change in the salt content.

TABLE IV

The rate of increase of decrease in the salt content of some of the drains per year

Serial No.	Name and site of the drain	Number of years on which rate is calculated	Rate of increase or decrease in salt content per year
1	Wan drain at R.D. 37,500	11	+2·3
2	Wan drain at wan minor crossing	13	+2·3
3	Mixture of wan drain and Khadir branch	14	+0·34
4	Sulki creek	13	+3·5
5	Mona drain at R.D. 13,200/1,400	13	—1·5
6	Mona drain at R.D. 135,500	12	+2·0
7	Mona drain at R.D. 327,500	12	+0·84
8	Lower Rani-Wah at R.D. 42,000	8	+71·5
9	Lower Rani-Wah at R.D. 238,500/228,364	8	+29·8

(d) *Amount of salt removed by the drains per year*

The drains perform double function. They not only remove the surface water, but also remove the salts from the soil. Table V (1940) gives the amount of salts removed by the drains per year. Though the salts removed by the drains every year are thousands of tons, yet the removal when taken into consideration with the total quantity of salts present in the catchment area of the drains is insignificantly small. The following example will make the point clear.

TABLE V

The total salts removed by some of the drains per year

Serial No.	Name and site of the drain	Average discharge in cusecs	Average total salts per 10^5 parts	Total salts removed per year (in tons)
1	Lower Rani-wah at R.D. 42,000	16·2	722·0	$10^5 \times 1{\cdot}03$
2	Mona drain at R.D. 13,200/14,000	14·3	74·4	$10^3 \times 9{\cdot}4$
3	Wagh drain at R.D. 30,000 Ahmadpur	97·6	52·95	$10^4 \times 4{\cdot}55$
4	Mona drain at R.D. 327,500	44·0	78·0	$10^4 \times 3{\cdot}02$
5	Ahmedpur Kot Nika drain at R.D. 50,000	32·5	73·20	$10^4 \times 2{\cdot}01$
6	Head Jurian Kassoke drain	3·6	27·6	$10^3 \times 0{\cdot}87$
7	Marh Salar drain at R.D. 79,000	14·0	46·3	$10^3 \times 5{\cdot}7$
8	Sukheki drain at R.D. 2,000	2·8	225·6	$10^3 \times 5{\cdot}6$
9	Marh chiniot drain at R.D. 16,000	50·1	124·3	$10^4 \times 5{\cdot}5$
10	Gujranwala drain at R.D. 1,000	11·4	58·0	$10^3 \times 5{\cdot}8$
11	Tail Shorey drain	47·5	34·0	$10^4 \times 1{\cdot}4$
12	Tail Mangoki drain	4·0	72·4	$10^3 \times 2{\cdot}6$
13	Tail Jhatanwali drain	21·5	40·1	$10^3 \times 7{\cdot}6$

Assuming that the average salt content of the catchment area of the Mona drain at R.D. 327,500 is 0·40 per cent, it will be necessary to reduce it to 0·20 per cent so that the soil comes within the permissible limits of salt content. The total catchment area of the drain is about 476 sq. miles. The depth of the soil crust may be taken as 8 ft. and the weight of one cubic foot of soil as 100 lb.

$$\text{Total wt. of the soil} = \frac{476 \times 1760 \times 1760 \times 3 \times 3 \times 8 \times 100}{2240} \text{ tons} = 47{\cdot}22 \times 10^8 \text{ tons}$$

$$\text{Total wt. of the salts to be removed from the above soil} = \frac{47{\cdot}22 \times 10^8 \times 0{\cdot}2}{100} \text{ tons} = 9{\cdot}44 \times 10^6 \text{ tons}$$

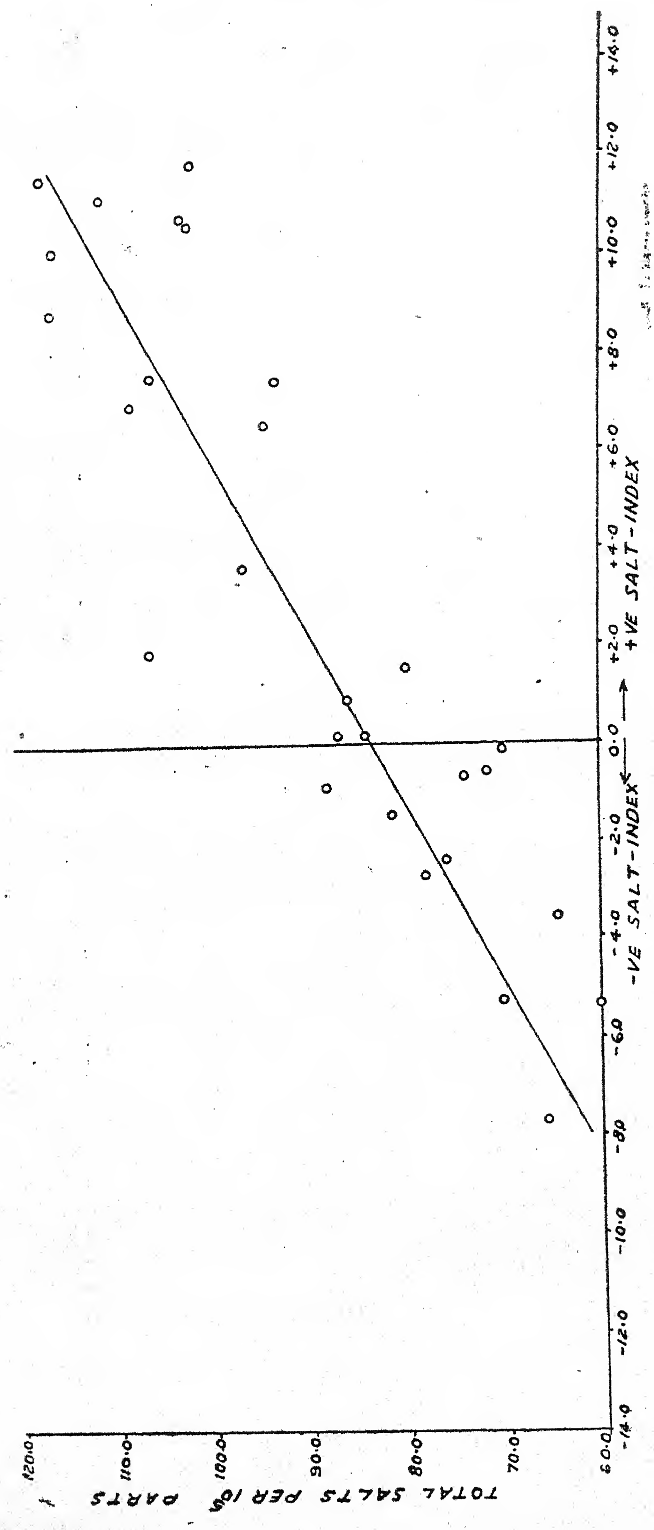

FIG. 4. Relation between salt index and total salts of the dbain waters

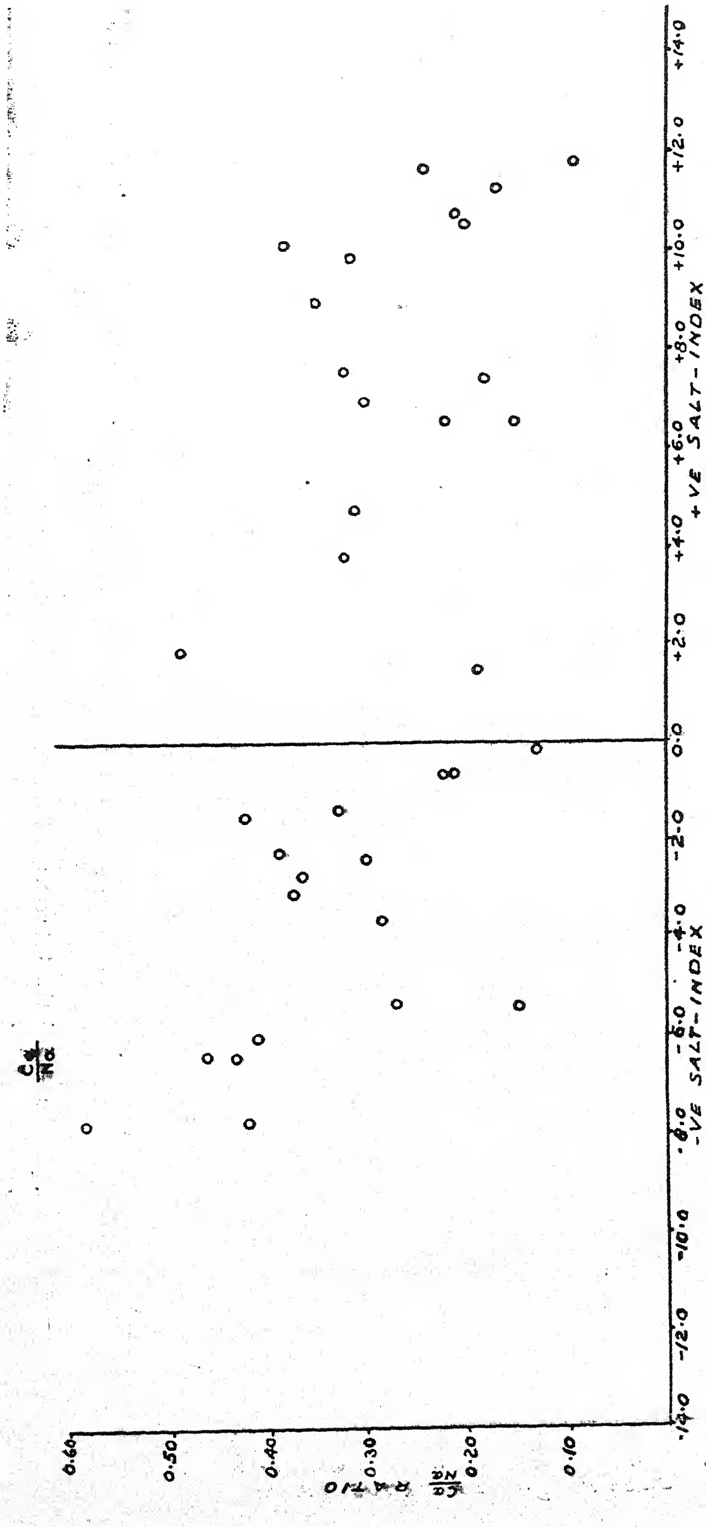

Fig. 5. Relation between salt index and Ca Na ratio of the drain waters

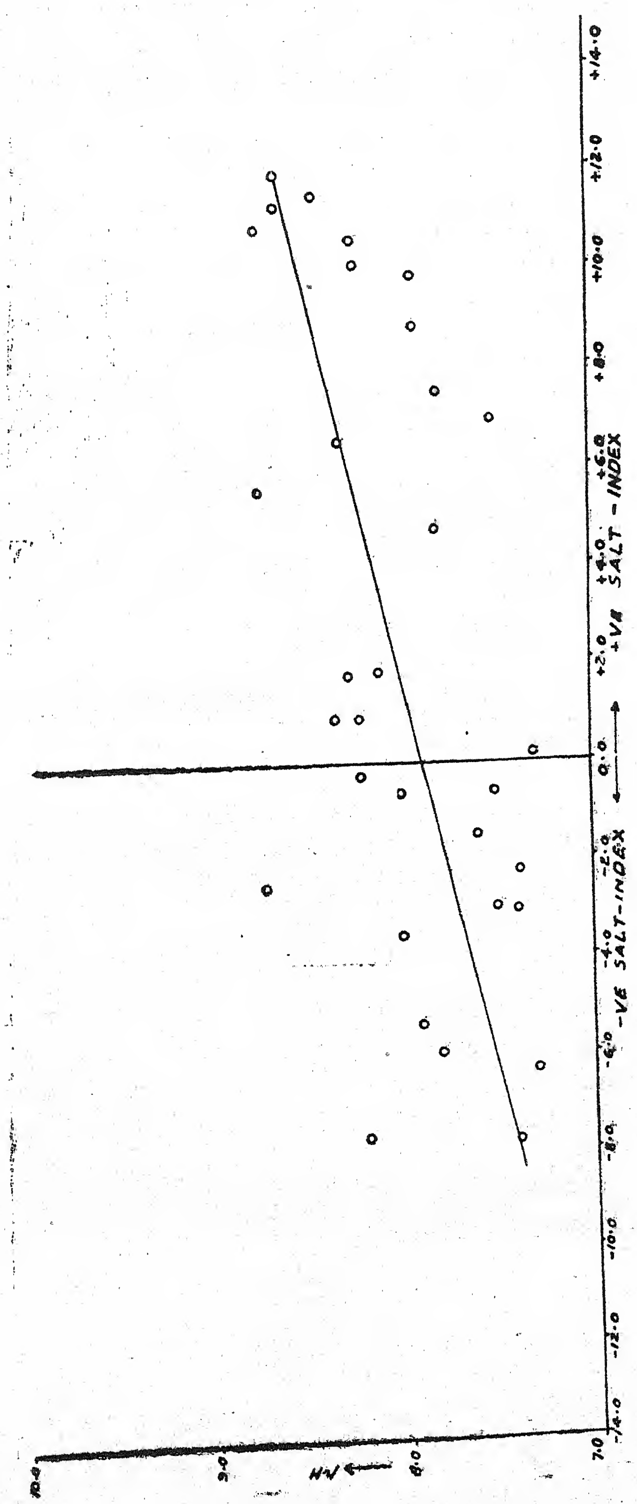

FIG. 6. Relation between salt index and pH

The average annual removal of the salts in the Mona drain is $10^4 \times 3{\cdot}02$ tons (*vide* Table V). Therefore the number of years required to remove $9{\cdot}44 \times 10^6$tons of salt $= 9{\cdot}44 \times 10^6 / 3{\cdot}02 \times 10^4$ about 312 years. Thus the reduction in salt content as affected by the drain is not appreciable.

(e) *Relation between salt index, total salts, calcium/sodium ratio, and* pH *value*

(i) Fig. 4 shows the relation between the salt index and the total salt content of the drains. The graph signifies that the total salt content is approximately a function of the salt index. For the positive salt index the salts increase with the increase in the salt index, while for the negative salt index the salts decrease with the increase in the salt index. Thus the drain waters unfit for irrigation contain mostly sodium salts, and the quantity of calcium decreases proportionately with the increase in total salts. The waters with negative salt index behave differently. The correlation of total salts with salt index is 0·94 and positive which is highly significant.

(ii) *Relation between the salt index and calcium/sodium ratio of the drain waters*

Fig. 5 shows the relation between the calcium/sodium ratio and salt index of the waters. Though there is a scatter of the points yet it is pointed out that the calcium sodium ratio increases with the increase in the negative salt index. The correlation of calcium/sodium ratio with salt index is 0·46 and negative. It shows that high Ca/Na ratio is associated with low salt index. Water containing high Ca/Na ratio possesses a highly negative salt index, and vice versa.

(iii) *Relation between the salt index and* pH *value*

Fig. 6 represents the relation between the positive and negative salt index and *p*H value.

The higher the positive salt index, the higher is the *p*H value. It is vice versa in the case of waters of negative salt index. But the agreement is not well marked. The results signify the importance of the introduction of calcium ions in making the waters fit for irrigation. It has been noticed that calcium permutite [1947] and calcium sulphate can be used for converting the positive salt index into negative one. This conversion would automatically change the unfit water into a fit one. The correlation of salt index with *p*H value is 0·66 and positive. It means high salt index is associated with high *p*H value.

(f) *Aquatic flora of the drains in relation to their salt content*

The drains are infested with many kinds of flora. But it has been observed that with the increase in total salts *Potamogenton pectinatus* increase in number and *Hydrilla* [1916] decrease in number. In drains of low salt content *Vallisneria* and *Hydrilla* predominate.

Summary

1. There is a close relationship between the conductivity and the total salt content of the drains
2. The drain waters are not very alkaline. The *p*H values range between 7·25 and 8·75.
3. The drains are removing several thousand tons of salts per year. But the process is very slow.
4. Except the lower Rani-wah drain, there is no significant change in the salt content of the drain waters per year.
5. Salt index is the real determining factor in the quality of the drain water.
6. The occurrence of *Potamogenton pectinatus* is an indicator of the high salt content in the drain water.

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A PRELIMINARY NOTE ON THE ESSENTIALOIL-BEARING PLANTS GROWING IN KASHMIR—PART III

By K. L. Handa, L. D. Kapoor and I. C. Chopra, Drug Research Laboratory, Kashmir State

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In continuation of the work [Chopra *et al.*, 1946 and 1947] on the study of the essential oil-bearing plants of Jammu and Kashmir a few more plants reputed for their aromatic properties were collected during botanical tours in the Kashmir valley.

The study of these plants has revealed that some of these yield a fair percentage of essential oil which can be economically exploited for medicinal and cosmetic purposes.

The studied plants are noted below.

1. *Xanthoxylum alatum Roxb.* (Vern. *Timbru*)

The plant is usually a shrub but at times attains the height up to 20 ft. It grows along the foot of the Himalaya from the Indus eastwards ascending to an altitude of 5,000 ft. usually in rather hot, dry places [Parker 1924]. In Kashmir the plant is common in the Jhelum valley below Uri (25 miles from the valley).

Every part of the plant possesses a peculiar aromatic pungent smell. Walking sticks and clubs are made from its stems and fragrant twigs are used as tooth brushes. In the indigenous system the fruits and bark are used in fevers, dyspepsia and cholera. [Chopra, 1933.]

For the study of the essential oil the fruit of this plant was obtained from Muzaffarabad district. On steam distillation a pale yellow oil with a peculiar odour was obtained with the following characteristics which have been compared with those of the foreign oil [Gildemiester and Hoffmann, 1922].

	Local oil	*Foreign oil*
Yield of oil from dry fruits	2·1 per cent	3 per cent
Sp. gravity	1·025 at 15°C.	0·8653 at 15°C.
Refractive index	1·475 at 20°C.	1·48131 at 20°C.

2. *Aegle marmelos* Corr. (Vern. *Bael*)

The tree is indigenous to India and is found wild all over the sub-Himalayan forests, in Bengal, south India and Burma. It is also cultivated at various places for the alleged medicinal properties of the fruit [Collett, 1921]. It is very common in the lower forests of Jammu Province. The unripe fruit is regarded as an astringent, digestive, stomachic and is said to be an excellent remedy for diarrhoea and dysentery [Chopra, 1933].

Both the fresh and dry fruits and leaves procured from Jammu were steam distilled. The yield of the essential oil from the fruits was rather poor. The leaves yielded quite a good quantity of the oil which has the following properties:

Yield of oil from fresh leaves	0·23 per cent
Yield of oil from dry leaves	0·54 per cent
Yield of oil from fresh fruit	Traces
Sp. gravity	0·807 at 15°C.
Refractive index	1·448 at 20°C.

3. *Juniper berries*

Juniper berries and the oil extracted from them are very ancient remedies and were used for digestive and diuretic purposes. Juniper oil in the commerce is much used for preparing the well known beverage 'gin' which owes its characteristic flavour to Juniper [Chopra, 1933]. There are three species of Juniper which grow in Kashmir: *Juniperus communis*, *J. macropoda* and *J. recurva*. Out of these species *Juniperus recurva* is rather scarce. Effort is being made to procure its berries and the results will be communicated in due course.

Juniperus communis Linn. (Vern. *Vither*). It is an ever-green shrub which grows at high altitudes from 9,000 to 14,000 ft. in the inner dry ranges of mountains. The ripe berries of the plant procured from the Sindh valley were steam distilled. The properties of the oil obtained from the berries are given below and are compared with those of the foreign oil [Parry, 1925]:

	Local oil	*Foreign oil*
Yield of oil from dry berries . .	0·77 per cent	0·5 to 1·05 per cent
Sp. gravity	0·9388 at 15°C.	0·865 to 0·890 at 15°C.
Refractive index	1·488 at 20°C.	1·475 to 1·488 at 20°C.

Juniperus macropoda Boiss (Vern. *Padam*). It is a medium sized tree which grows in inner dry ranges of the Himalayas at altitudes of 8,500 to 14,000 ft. It is very common in the Gurez valley. The wood of the tree is much used for pencil making. The dry berries of the plant procured from Gurez valley yielded a sweet smelling oil on steam distillation which had the following properties:

Yield of oil from dry berries	3·3 per cent
Sp. gravity	0·8571 at 15°C.
Refractive index	1·473 at 20°C.

4. *Ferula Jaeschkeana* Vatke (Vern. *Hing*)—

A number of *Ferula* species grow wild in the Kashmir valley and in the bordering hills. The important species are *Ferula narthex*, *F. thomsoni* and *F. jaeschkeana*.

The authentic specimens of the gum resin, asafoetida, which oozes out of incision on the roots of the plant could not be made available and only the roots and dry fruits of *F. jaeschkeana*, which could be procured, were studied. The gum resin (asafoetida) will be studied and the results communicated later on.

F. jaeschkeana which is an erect perennial herb grows commonly on the slopes of mountains at altitudes of 6,000 to 12,000 ft. above the sea level. It is reported to be common in Baluchistan. In Kashmir it grows commonly in the Gulmarg, Verinag, Gurez and Kamri ranges. The gum resin (asafoetida) is used locally as a condiment and in the treatment of flatulence [Bamber, 1916].

The roots and mature fruits of the plants were collected from Verinag and Gulmarg ranges and the essential oil distilled from these, had the following properties:

Yield of oil from dry roots	1·2 per cent
Sp. gravity	1·149 at 15°C.
Refractive index	1·453 at 20°C.
Yield of oil from dry fruits	3·8 per cent
Specific gravity	0·857 at 15°C.
Refractive index	1·464 at 20°C.

5. *Archangelica officinalis* (Var. *Himalaica*)—

It is a large perennial erect herb assuming the size of a small tree. It is commonly found in Kashmir near the water channels at altitudes from 8,000 to 13,000 ft. especially in the hills near Gulmarg and Gurez.

The fruit and the roots of the plant are reputed for their aromatic properties. In Europe the plant *A. officinalis* is official and its essential oil is used as a flavouring agent in confectionary and in liquors [Bamber, 1916].

The fruits and roots were collected from Gulmarg and on steam distillation the oil yielded had the following properties:

Yield of oil from dry roots	0·8 per cent
Sp. gravity	0·8922 at 15°C.
Refractive index	1·4478 at 20°C.
Yield of oil from dry fruits	3·8 per cent
Sp. gravity	0·887 at 15°C.
Refractive index	1·464 at 20°C.

6. *Carum carui* Linn., Caraway (Vern. *Zira*)—

Caraway consists of the dried ripe fruits of *Carum carui* an erect biennial herb indigenous to and cultivated in North and Central Europe, chiefly in Holand and in Central Asia. In India it is cultivated as a summer crop in the hills of Baltistan, Kashmir, Kamaon, Garhwal, etc. at an altitude of 9,000 to 12,000 ft. In Kashmir the plant commonly occurs in Astore, Drawa, Gurez, Skardu and it is also cultivated in the valley. The plant is cut when the fruit is ripe, which is then separated by thrashing. It is largely used in both the Indian and western systems of medicine as stomachic and carminative. Caraway oil is used as carminative. Caraway oil is also used for flavouring wines and scenting soaps in perfumery [Chopra, 1933].

For the distillation of the essential oil caraway seeds growing in Skardu, Gurez and Baghbanpura were procured and the properties of the oil thus obtained were studied. These are compared with the standards laid down in *British Pharmaceutical Codex*, 1934 :

Locality	Baghbanpura	Gurez	Skardu	B.P.C. Standard
Altitude	5,500 ft.	7,900 ft.	7,700 ft.	..
Yield of oil	4·3 per cent	6·8 per cent	8·5 per cent	3·5 to 6 per cent
Sp. gravity	0·9095 at 15°C.	0·8902 at 15°C.	0·8907 at 15°C.	0·910 to 0·920 at 15°C.
Refractive index	1·491 at 20°C.	1·486 at 20°C.	1·485 at 20°C.	1·485 to 1·492 at 20°C.

A perusal of the data shows that the caraway growing in various parts of Kashmir gives pretty good yield of oil which is up to *B.P.* and *B.P.C.* standard.

7. *Prangos pabularia* Lindle (Vern. *Komel*)

It is a large perennial herb which grows at altitudes from 6,000 to 11,000 ft. in Kashmir. The plant is considered to have carminative, diuretic and emmengogue properties. The leaves, flowering tops and dry roots of the plant procured from Pir Panjal range, on steam distillation gave essential oil with the following properties :

Yield of oil from dry leaves and flowering tops	0·65 per cent
Yield of oil from dry roots	1·02 per cent
Sp. gravity	1·129 at 15°C.
Refractive index	1·454 at 20°C.

8. *Origanum vulgare* Linn. (Wild Marjrom; Vern. *Satra*)

The plant grows wild commonly in the temperate Himalayas at altitudes from 6,000 to 12,000 ft. In Kashmir it is commonly found from 5,000 to 9,000 ft. in forests in the valley.

It is reported to be eaten at certain places as a pot herb. In the indigenous system of medicine the plant is used as an aromatic, stimulating tonic in diarrhoea, rheumatism and in earache [Chopra, 1933].

The plant was collected from the neighbourhood of Gulmarg and on steam distillation the essential oil had the following characteristics :

Yield of oil	0·76 per cent
Sp. gravity	0·933 at 15°C.
Refractive index	1·477 at 20°C.

9. *Senecio jacquemontianus* Benth (Vern. *Poshkar*)—

Amongst the many species of *Senecio* which grow wild in abundance in Kashmir the study of *S. jacquemontum* was undertaken for its aromatic properties. It is a large herb and the roots particularly give aromatic odour. The plant grows in the Himalayas at altitudes of 10,000 to 13,000 ft. above the sea level [Bamber, 1916]. In Kashmir it grows wild in Gurez valley.

The roots of the plant were collected during the autumn from Rajdhani (11,000 ft.). On steam-distillation the roots yielded essential oil with the following characteristics :

Yield of oil	1·2 per cent
Sp. gravity	0·9545 at 15°C.
Refractive index	1·483 at 20°C.

10. *Chaerophyllum villosum* Wall (Vern. *Jangli Gajar*)—

It is a perennial erect herb often found in the temperate Himalayas at altitudes from 5,000 to 12,000 ft. In Kashmir the plants grow abundantly in pine forests and the roots are eaten by the local people as wild carrot.

The whole flowering plant was steam-distilled and the essential oil obtained had the following characteristics:

Yield of oil	0·98 per cent
Sp. gravity	0·9742 at 15°C.
Refractive index	1·463 at 20°C.

11. *Achillea millefolium* Linn. (Vern. *Momadru, Chopandiga*)—

It is a common plant found in temperate Himalayas at altitudes of 6,000 to 11,000 ft. In Kashmir it is found growing in abundance as a wild weed near the cultivated fields or forest blanks around the valley. The flowering heads of the plant were collected for the distillation of essential oil which was obtained only in traces.

12. *Eryngium caeruleum* Bicb. (Vern. *Dudhali*)—

It is a medium sized erect herb growing common in Kashmir valley at altitudes of 5,000 to 6,000 ft. The root of the plant is taken as an aphrodisiac and nervine tonic. The plant was collected from neighbourhood of Srinagar and on steam-distillation it yielded traces of essential oil.

13. *Anthemis noblis* Linn. (Vern. *Babune-ke-Phul*)—

It is a small herb growing wild and is also cultivated in the temperate Himalayas for the medicinal properties recognized in the Tibbi system of medicine as stimulant and tonic [Chopra, 1933]. The flowers were collected locally but on steam distillation only traces were found.

The physical properties of the oils from the three plants mentioned above could not be studied as sufficient amounts could not be obtained by distillation.

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A NEW SEEDLING DISEASE OF BRINJALS

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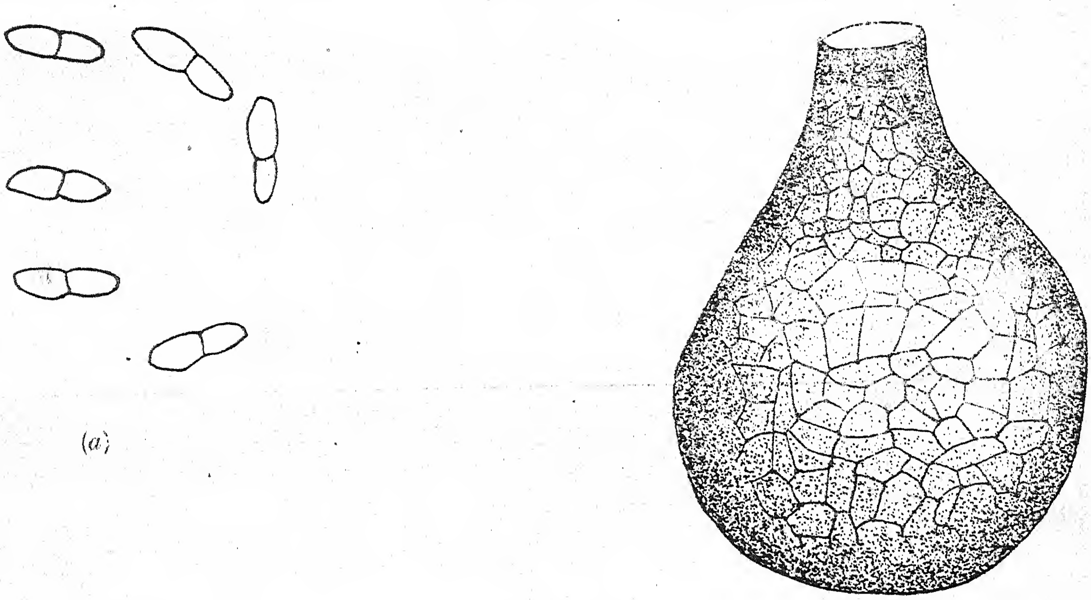
(With two text figures)

A DISEASE causing leaf spots in brinjal seedlings was found in the Departmental Seedling Nursery at Jessore (Bengal) in November, 1945. The spots are small, brown in colour, and somewhat angular in the beginning. They enlarge to become circular or elliptical or irregularly elliptical and possess a well defined margin. In the older spots the central region becomes papery and transluscent. Sometimes shot-holes are also formed. The spots on enlargement show a marked tendency to be confined between the principal lateral veins of the leaf lamine, with the result that irregular spots are formed when their margins run parallel to the veins.

Causal organism

The fungus associated with the above symptoms on brinjal seedlings is an *Ascochyta* species producing numerous, half-immersed, brown, sub-globose, or slightly irregular, papillate pycnidia having distinct ostioles. The wall of the pycnidium is of thin brown parenchyma with dark walls. The spores are at first continuous, ellipsoid or cylindrical, with rounded or blunt ends. The mature spore develops, a single septum in the middle and is stout, cylindrical, or oblong, with rounded or blunt ends. There is a waist-like constriction of the side walls where these come in contact with the median septum. Two guttulations are also seen in each of the two cells of the spore. The unseptate spores measure $7{\cdot}8\mu \times 3\mu$. ($4\text{-}11 \times 3\mu$.), while the septate ones measure $11{\cdot}0 \times 4\mu$. ($10\text{-}913 \times 3\text{-}5$) each. *Taxonomy.* Several species of *Ascochyta* have been recorded on Solanaceae outside India, but not on the cultivated brinjal, *Solanum melongena.* Thus, *A. petuniae* Speg., *A. nicotianae* Pass., *A. physalina* Sacc., *A. daturae* Sacc. [Saccardo, (i)], *A. solanicola* Oud., *A. alkekengi* Mass. [Saccardo, (ii)], *A. dulcamarae* Bubak. [Saccardo, (iii)] and *A. lyco persici* Brun [Grove, 1935] have been reported. No records of *Ascochyta* species on Solanaceae have been made in India [Butler and Bisbey, 1931 ; Uppal *et al*, 1934 ; Mundkur, 1938]. The descriptions of the species reported on Solanaceae are presented in Table I, and compared with that of the fungus on brinjals.



(a) (b)

Pycnidia of *Ascochyta Melongenae* n. sp. with pycnospores

(a) Pycnidia × 300

(b) Pycnospores × 1800

Q

TABLE I

Description of Ascochyta *sp. reported on Solanaceae compared with the fungus on* Solanum melongena *in Bengal*

Name of fungus	Host	Description
Ascochyta petunia Speg	*Petunia*	Pycnidia—somewhat large, dark coloured; size, 100-130μ Spores—hyaline, cylindrical, elliptic, median septate, without any constriction: size, 5-8×2μ
A. nicotianae Pass.	*Nicotiana tabacum*	Spores—ovoid oblong, median septate, hyaline or granulate (no spore measurements)
A. daturae Sacc.	*Datura stramonium*	Pycnidia—aggregated on the upper side of the leaf, somewhat rounded, 100μ in diameter Spores—cylindrical to oblong, both ends rounded, one septate, size, 7-8×3μ
A. physalina Sacc.	*Physalis Alkekengi*	Pycnidia—immersed on the upper side of the leaf Spores—oblong, cylindrical, constricted, one septate, size, 25-28×8μ. 2-4 guttulate
A. solanicola Oud.	*Solanum nigrum*	Pycnidia—epiphyllous, rare, brown, central pore prominent, diameter 200μ spores—rod-shaped, both ends rounded hyaline, one septate, without constriction; size, 10-12×2·5μ
A. alkekengi Mass.	*Physalis alkekengi*	Pycnidia—epiphyllous, dot-like, membranous, pale brown, 120-150μ in diameter spores—ovoid, hyaline, continuous, or one septate; size, 5-10×2·5-4μ
A. dulcamerae Bubak	*Solanum dulcamara*	Pycnidia—immersed in the mesophyll, globose, depressed, 100-150.μ diameter spores—cylindrical, straight or rarely curved, apex rounded, at first continuous later one septate; size, 7-9×2·4μ
A. lycopersici Brun.	*Lycopersicum esculentum*	Pycnidia—scattered or aggregated on swollen spots, sub-epidermal, erumpent sub-globose, brown to brownish-black, slightly papillate, pierced by a pore or two; 100-250μ diam, texture, thin parenchymatous, cells clear pale brown darker round the outside spores—ovoid (4·5×2·3μ), then sub-cylindrical, hyaline, continuous, then one septate slightly constricted with 2 or no guttules; size, 9.5×3.5. (4·5-15×2·5-5μ) issuing in a whitish or flesh coloured tendrils, sporophores, short, simple and filiform
Ascochyta Sp.	*Solanum melongena*	Pycnidia—numerous, half immersed, brown sub-globose to irregular, papillate and ostiolate, wall cells of thin brown parenchyma with dark walls; size, 90-217μ. spores—ellisoid cylindrical, with rounded or blunt ends, one septate with constriction two guttulations in each cell; size, 11.35×4μ

The spore measurements of the species on brinjals are greater than those of other species excepting *A. physalina*, the spores of the last mentioned species being about twice that of any other. The spores are distinguishable from those of *A. solanicola* in being very much stouter in their constrictions at the septal region, and in the presence of guttulations in the cells.

Thus the fungus found on brinjal seedlings in Bengal does not seem to belong to any of the known species of *Ascochyta* on Solanaceae. The name, *A. melongenae* n. sp., is proposed to accommodate it.

TECHNICAL DESCRIPTION

Pycnidia numerous, half-immersed, globose, sub-globose to slightly irregular, brownish, somewhat papillate and distinctly ostiolate; pycnidial wall of thin brown parenchymatous cells; size

$90\text{-}217\mu$, averaging 151μ in diameter. Spores ellipsoidal with rounded ends, or somewhat cylindrical with rounded or blunt ends; spores on development become one septate, slightly elongated, cylindrical, and have stout walls having waist-like constriction at the septum, and two guttulations in each cell. The unseptate spores measure $7{\cdot}0 \times 3\mu$, with a range of $4\text{-}11 \times 3\mu$. The septate spores measure 11×4, with a range of $10\text{-}13 \times 3\text{-}5\mu\text{-}4{\cdot}98\mu$.

Habit on living leaves of *Solanum melongena* seedlings in Jessore, Bengal; collected by S. Y. Padmanabhan in November, 1945. Type specimen deposited in Herb. Crypt. Ind. Orient, New Delhi.

Pycnidia multa, semi-inserta, globosa, sub-globosa, vel aliquatinus irregularis, brunnea, quadantenus papillata et distincte ostiolata. Latera pycnidiu constituunter ex cellulis parenchymaticis brunneis et tenuis, quarum mensura est $90\mu\text{-}217\mu$ et generatim circa 151μ. Sporae ellipsoidae cum extremis roundis vel hebetibus. Sporae crescendo fiunt uniseptatae, aliquatenus elongatae, cylindricae, cum crasso latere, circa septum coarctato, cum duabus guttulationibus in singulis cellulis; inseptate sporae sunt $4\text{-}11 \times 3\text{-}5\mu$.

Habitat in folus plantularum *Solani melongenae* in Jessore, Bengal Collegit S. Y. Padmanabhan, mense novemberi, 1945.

Exemplar servatur in Herb. Crypt. Ind. Orient, New Delhi.

CONTROL

The incidence of the disease in the beds was not severe. It was noticed in its initial stages before it could do much damage. Complete control was effected by plucking out the affected leaves in the beds and spraying the seedlings once with half per cent Bordeaux.

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